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Effect of seasonal wrestling training and unavoidable interventions on selected physiological parameters

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The Effect of Seasonal Wrestling Training and Unavoidable Interventions on Selected Physiological Parameters

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by
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ABSTRACT

Title of Thesis: The Effect of Seasonal Wrestling Training and Unavoidable Interventions on Selected Physiological Parameters

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The purpose of this study was to investigate, 1) the effect of seasonal wrestling training on aerobic and anaerobic power, physical working capacity (170), resting, maximal and recovery heart rate, 2) to determine the effect of unavoidable interventions in the training program, and 3) to determine whether peak levels were found on the parameters just prior to the College and National wrestling championships. The research design selected was a repetitive bi-weekly testing schedule for physical working capacity (170), recovery heart rate and anaerobic power, and a monthly testing schedule for resting, maximal and recovery heart rate and maximum oxygen uptake. The data were analyzed by a one-way analysis of variance and a Tukey test was applied to judge appropriate contrasts. The results indicated that the 18 weeks of wrestling training had a significant ($p < .05$) effect on maximum oxygen uptake, resting and recovery heart rate and the heart rate after 12 minutes of submaximal work. There were apparent differences in the other parameters investigated, however, they were not significant. The unavoidable interventions in the training program were the examination period and the Christmas holidays, which extended from December sixth to the 18th and December 19th to January third, respectively. The interventions were detrimental to the fit-

ness level of the present sample. The test values obtained immediately following the intervention period were less favourable than the pre-training values for all parameters investigated with the exception of the five minute recovery heart rate following 12 minutes of submaximal work. This finding indicated that the training effect that had occurred prior to the intervention period had totally deteriorated over the intervention period. Peak levels of fitness were achieved just prior to the College and National championships, thus suggesting that the wrestlers were not experiencing symptoms of overtraining or had reached peak fitness levels at an earlier date and were now at a maintainance or detraining state.

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Chapter 1

INTRODUCTION

Statement of the Problem

The purpose of this study was to investigate, 1) the effect of seasonal wrestling training on aerobic and anaerobic power, physical working capacity (170), resting, maximal and recovery heart rate, 2) to determine the effect of unavoidable interventions in the training program, and 3) to determine whether peak levels of fitness were achieved by the wrestlers just prior to the College and National wrestling championships.

Significance

There are many factors which govern success in amateur wrestling. Wrestling authorities (Jesse, 1976) have outlined that the integral features required for wrestling success include development of the cardiovascular and respiratory system, strength, explosive power, muscular endurance, flexibility, agility, technical skill and a high level of motivation and self-confidence. At present, there exists some controversy as to whether physiological or psychological readiness is the major limiting factor to success at high level competition. An analysis of this controversy, although interesting, is outside the scope of this study and whether it is possible to say that one area is more of a limiting factor than the other is beyond the jurisdiction of this investigator.

In the coaching situation, many coaches often think that the fitness levels of their athletes are improving as the season progresses and that they reach peak levels of fitness at the time of the College and National championships. There are very few coaches that employ a regular testing schedule to examine the improvement of the athletes' fitness level and to evaluate the training program for the improvement of desirable physical condition.

To present date, very little research has been conducted which monitors cardiovascular adaptations over the course of a competitive wrestling season on college wrestlers. No research has been done that determines the effect of unavoidable interventions in the training programs of college wrestlers on $\dot{V}O_2$ max, anaerobic power, PWC_{170}, resting, recovery and maximal heart rate.

The unavoidable interventions in this study were the examination period and the Christmas holidays. Since many college athletes are required to maintain a certain academic average to remain a member of an athletic team, the examination period is a stage in the training program where the duration of the daily athletic training is reduced. This reduction in training could result in deterioration of the fitness levels. Additionally, since many college athletes attend colleges away from their home town, the Christmas holidays is a period when most athletes re-unite with their family for the festive season.

In many cases, once the athlete leaves the college campus for the festive season he fails to follow a proper training schedule and adhere to a proper diet. When combining an inadequate training schedule and a modified diet, a definite possibility exists that the Christmas break is very detrimental to the fitness level of the college athletes.

The studies that have been done to present have reported the differences from pre- to post-training without specifically indicating whether there were any fluctuations in the investigated parameters over the course of the investigative period. Kelly, Korney and Kalm (1978), Schreiber (1973) and Shaver (1974a, 1974b) have investigated the effect of seasonal wrestling training on various physiological parameters. However, these studies were limited to the pre- and post-test method and consequently, the post-training values could not be verified as to whether they were indeed the peak levels of fitness achieved by the wrestlers over the training schedule.

This study was an exploratory project which employed a bi-weekly and monthly repetitive testing schedule on $\dot{V}O_2$ max, anaerobic power, PWC_{170}, resting, recovery and maximal heart rate to investigate, 1) the effect of seasonal wrestling training; 2) to investigate the effect of the examination period and the Christmas holidays; and 3) to determine whether peak levels of fitness were achieved by the wrestlers just prior to the College and National championships.

Delimitations

1. Eleven potential members of the Lakehead University varsity wrestling team served as subjects ranging from 18 to 24 years of age.

2. Dependent physiological variables were aerobic and anaerobic power, PWC_{170}, resting, and maximal and recovery heart rate.

3. Unavoidable interventions included the examination period

and Christmas break extending from December 6, 1978 to January 3, 1979.

4. Diurnal variations were avoided by testing the subjects at the same time of the day each testing session.

5. Investigative period was 18 weeks in duration commencing October 30, 1978 and terminating March 3, 1979.

Limitations

1. Subjects participated on a voluntary basis.

2. The ability to control subjects to exert maximum effort on $\dot{V}O_2$ max test and anaerobic power test.

3. The ability to control subjects to follow instructions.

4. The possibility existed that serious injuries would occur thus preventing completion of training.

5. An alpha level of .05 was established as the level of significance for statistical testing.

Definitions

Aerobic power ($\dot{V}O_2$ max): the ability of the oxygen transport system to take up, transport and give off oxygen to the working muscles.

Anaerobic power: a measure of work done in the absence of oxygen and expressed per unit of time.

Maximal Heart Rate (MHR): the greatest number of ventricular contractions by the heart in one minute.

Physical Working Capacity (170) (PWC_{170}): the working intensity in kpm/min which the subject could perform at a pulse rate of 170 beats/min.

Potential varsity team members: wrestlers who took part in regular training and were considered by the coach to be candidates for the Great Plains Athletic Conference wrestling team.

Resting Heart Rate (RHR): the number of ventricular contractions by the heart in the resting state in one minute.

Recovery Heart Rate following maximum effort (RHR max): the number of ventricular contractions by the heart/min after a five minute rest period following a maximal heart rate.

Recovery Heart Rate following submaximal work load (RHR sub): the number of ventricular contractions by the heart/min after a five minute rest period following a submaximal work load.

Unavoidable Interruptions: interruptions in the training schedule that subjects have no control over, for example, examination period, and Christmas holidays.

Chapter 2

REVIEW OF LITERATURE

Aerobic power

In the assessment of an individual's capacity for prolonged work the determination of his maximal oxygen uptake ($\dot{V}O_2$ max) per unit time has a fundamental importance. Mathews and Fox (1976) indicated that the energy demand for amateur wrestling is met through aerobic and anaerobic metabolism. Such being the case, it is imperative that the wrestler develops the aerobic and anaerobic energy systems maximally if he is to experience high level success.

The effects of training on the amount of oxygen that can be consumed per minute during maximal exercise has been studied extensively; there is little doubt that it is increased with training, (Åstrand, 1952; Åstrand, Erikson, Hylander, Engstrom, Karlberg, & Wallstrom, 1968; Fox, Bartels, Billings, Mathews, Bason, & Webb, 1973; Fox, Bartels, Billings, O'Brien, Bason, & Mathews, 1975; Frick, Sjogren, Persasalo, & Pajunen, 1970).

In a recent review by Pollock (1973) covering a wide selection of studies concerning the effect of endurance training on $\dot{V}O_2$ max, the reported improvements vary from 0 to 43 percent. Pollock (1973) concluded that the initial level of fitness (natural endowment, habitual activity), intensity, frequency, duration of training, and age are factors that influence the improvement of $\dot{V}O_2$ max.

Ekblom, Åstrand, Saltin, Stenberg, and Wallstrom (1968) trained ten healthy male subjects (aged 19 - 27) in a cross-country endurance running program interspersed with interval sprints. The program was followed for 45 to 75 minutes/day, three days/week for 16 weeks. During the distance running the heart rates varied between 130 and 170 beats/min and during the sprints, the heart rates fluctuated between 150 and 170 beats/min.

Maximum oxygen uptake was measured utilizing a bicycle ergometer both before and after the training program. A significant improvement in $\dot{V}O_2$ max of 16.2% (3.15 to 3.68 liters/min) was reported. The improvement was attributed to increased maximal cardiac output and increased arterio-venous oxygen difference. These findings are in accordance with the reported finding of Ekblom (1969a, 1969b), Faria (1970), Hartley, Grimby, Kilbom, Nilsoon, Åstrand, Bjure, and Saltin (1969), Naughton and Nagle (1965), Shephard (1968), and Seigel, Blomquist, and Mitchell (1970).

Sharkey and Holleman (1967) divided 16 subjects (aged 18 - 19) into three training groups and a control group. The training groups exercised at heart rates of either 120, 150, or 180 beats/min for ten minutes/day, three days/week over six weeks. Significant improvements in $\dot{V}O_2$ max were found only in the training group exercising at 180 beats/min.

Kelly et al (1978) investigated the effect of five months of wrestling training on cardiovascular fitness, muscular strength and endurance and body composition. $\dot{V}O_2$ max was determined on 19 subjects during the pre-season, peak-season and post-season utilizing a treadmill. $\dot{V}O_2$ max values of 58.6, 61.0, and 57.2 ml/kg/min were reported, respectively. Post-season data were collected five weeks following the season's conclusion. Six of the 11 varsity team members were National qualifiers. The mean peak-season $\dot{V}O_2$ max for this group was 65.7 ml/kg/min.

The relatively small changes found in $\dot{V}O_2$ max over the competitive season were attributed to the year round training that the majority of the wrestlers underwent.

The findings of Kelly et al (1978) are in accordance with the findings of Nagle, Morgan, Hellickson, Serfass, and Alexander (1975) in their study of Olympic contenders and Saltin and Åstrand (1967) in their study of National team wrestlers. However, they are considerably higher than the findings of Gale and Flynn (1974) in their investigation of maximum oxygen consumption of high-ability wrestlers. $\dot{V}O_2$ max was determined on 19 potential candidates for the U.S. Olympic team. A mean $\dot{V}O_2$ max of 53.0 ml/kg/min was found. There were no differences in the means of the aerobic power of the 48 to 100 kg group who were selected to the Olympic team (N=9), 54.0 ml/kg/min, and those who did not (N=8), 55.0 ml/kg/min. The heavyweight wrestlers (N=2) had $\dot{V}O_2$ max values lower than 40.0 ml/kg/min; neither were selected for the team.

Nagle et al (1975) attempted to determine the characteristics of successful and unsuccessful wrestlers. Of 42 potential candidates for the 1972 U.S. Olympic freestyle wrestling team, 25 completed psychological and physiological tests. Physiological measures included maximal heart rate, $\dot{V}O_2$ max and submaximal exercise heart rates. The findings indicate that the successful wrestlers (N=10) when compared to the unsuccessful wrestlers (N=15) had, a) lower maximal exercise heart rates (173 compared to 180 beats/min); b) higher $\dot{V}O_2$ max values (60.9 compared to 55.9 ml/kg/min) and c) lower submaximal exercise heart rates (127 compared to 143 beats/min).

Parnat, Viru, Savi, and Nurmekivi (1975) investigated cardiovascular responses during exercise in athletes specializing in different events. Subjects (N=95) were representatives of cycling, cross-country skiing, running, swimming, decathlon, basketball and volleyball. Results indicated that the cyclists (N=8) had the highest $\dot{V}O_2$ max of 69.7 ml/kg/min, with the highest individual value of 85.0 ml/kg/min. Following the cyclists in respective order were the cross-country skiers (63.5 ml/kg/min), runners (62.2 ml/kg/min), swimmers (56.5 ml/kg/min), decathlonists (55.1 ml/kg/min), basketball players (55.3 ml/kg/min), and volleyball players (54.4 ml/kg/min).

In an investigation of body composition and $\dot{V}O_2$ max of exceptional weight-trained athletes Fahey, Akka and Rolph (1975) found the mean $\dot{V}O_2$ max to be 48.8 ml/kg/min. Subjects were representatives of shot put, discus throwing, body building, power lifting, wrestling and Olympic lifting. The sample included three record holders, eight world class athletes and 19 national class competitors. The highest $\dot{V}O_2$ max was reported for a N.C.A.A. wrestling champion of 165 pounds (76.0 ml/kg/min).

Nagle and Pellegrino (1973) investigated changes in $\dot{V}O_2$ max of high school runners over a competitive track season lasting 10 weeks. Six runners, aged 14 to 17 served as subjects. In addition to determining $\dot{V}O_2$ max on a motor driven treadmill each subject was tested on a performance run of one mile. Performance times improved by an average of 4.0% with an associated increase in $\dot{V}O_2$ max of 6.2%.

Saltin and Åstrand (1967) investigated $\dot{V}O_2$ max in 95 male and 35 female athletes all representing Swedish National Teams in 19 different sports. Many of the subjects were European, World, or

Olympic champions. All subjects were brought to their maximum work by using either a bicycle ergometer, treadmill, or a combination of ergometers. The mean maximum oxygen uptake for the 15 males with the highest value was 5.75 L/min with an upper extreme of 6.17 L/min. As a team, the five cross-country skiers achieved the highest value of 85.1 ml/kg/min. The wrestlers (N=10) ranked only higher than the weight lifters and the untrained in maximum oxygen uptake with an average value of 57.0 ml/kg/min.

The initial level of fitness plays a vital role in depicting increases in $\dot{V}O_2$ max from pre- to post-training. Montgomery and Ismail (1977) studied the effect of a four-month physical fitness program on high and low-fit groups matched for age. Both groups (N=12) performed graded exercise tests at the beginning and after the training program consisting of calisthenics, jogging and recreational activities. The low-fit group increased their maximum oxygen uptake by 16.0% (35.5 to 41.1 ml/kg/min), whereas the high-fit group failed to show an improvement (49.8 to 49.3 ml/kg/min).

While investigating maximal heart rate and maximum oxygen uptake of long distance runners and other athletes, Koeslag and Sloan (1976) found that the long distance runners (N=11) had lower maximal heart rates than swimmers, oarsmen, squash, badminton, and rugby football players (182 compared to 194 beats/min). Additionally, the runners had a higher $\dot{V}O_2$ max than the other group of athletes (67.8 compared to 58.2 ml/kg/min).

The $\dot{V}O_2$ max of the runners reported by Koeslag and Sloan (1976) is considerably lower than the findings of Saltin and Åstrand (1967) and Costill, Fink, and Pollock (1976). However, they are of the same order as that of endurance athletes reported by Hermanson and Anderson (1965) of 4.8 L/min; 71 ml/kg/min. The $\dot{V}O_2$ max reported for the non-runners by Koeslag and Sloan (1976) are considerably higher than the findings of Kollias, Buskirk, Howley and Loomis (1971) for graduated high school football players preparing to enter college football (50.1 ml/kg/min), however, they are of the same order as the findings of Smith and Byrd (1976) for college football players.

Green and Houston (1975) conducted a study on two elite junior ice hockey teams with players ranging in age between 16 and 20 years to determine the effect of a season of ice hockey on energy capacities and associated functions. All players were measured on an extensive battery of laboratory tests at the beginning and end of the hockey season (five months). Their findings showed pre- to post-season changes in $\dot{V}O_2$ max of significant increases of three percent ($\underline{p} < .05$), Forced Expiratory Volume for one second (4.37 vs 4.44 L/min), and maximal exercise $\dot{V}_E$ (128.0 vs 128.1 L/min) and maximal heart rate (192 vs 191 beats/min). Additionally, anaerobic capacity improved significantly ($\underline{p} < .05$) by 16.3% and anaerobic power by 4.7% ($\underline{p} < .05$) when expressed in meters/sec (1.65 vs 1.77).

Parnat, Viru, and Nurmekivi (1975) investigated the aerobic and anaerobic work capacity of middle-distance and long-distance runners during various periods of all-year-round training. The repeated assessments were carried out on 18 sportsmen in December, March and May. The observations revealed that the changes in $\dot{V}O_2$ max and in the oxygen debt during various periods of training were insignificant. From December to March the aerobic work capacity in ten runners decreased, while it increased in the case of eight runners. In twelve cases the changes in the values of $\dot{V}O_2$ max changed by 12 to 28%. During the pre-competition period (March to May) the aerobic work capacity of eleven sportsmen increased, and five decreased. During that period the changes in $\dot{V}O_2$ max were as low as 2 to 12% in 10 cases and 12 to 30% in six cases. Only two runners had a stable $\dot{V}O_2$ max. It was concluded that the aerobic work capacity varies more intensively in the case of runners with low fitness.

Douglas and Becklake (1967) conducted a study on four university hockey players to investigate the effect of seasonal training on maximal cardiac output ($\dot{Q}$), heart rate, oxygen uptake and minute ventilation ($\dot{V}_E$). Each subject was exercised maximally before and after four months of training, with readings taken at several submaximal work loads as well as in the range of maximal capacity. The findings indicate that although each subject increased his maximal working capacity after training, maximal heart rate, $\dot{Q}$, $\dot{V}O_2$ max, and $\dot{V}_E$ showed no significant change.

Although many studies indicate that training results in an increased $\dot{V}O_2$ max, the increment is dependent upon several factors. For example, initial level of fitness and the nature of the training program are of prime consideration. The available literature on $\dot{V}O_2$ max relating to wrestlers indicates that wrestlers are not as aerobically conditioned as cross-country skiers, cyclists, and long-distance runners. Rather, they have $\dot{V}O_2$ max values comparable to soccer, football and basketball players and swimmers.

Although, the sport of wrestling requires many other attributes: for example, technique, speed, flexibility, strength and balance in addition to aerobic power, the findings of Kelly et al, 1978; Nagle et al, 1975; Fahey et al, 1975; and Gale and Flynn, 1974; support the contention that cardiovascular conditioning is an extremely important component required for wrestling success.

Anaerobic Power

The methods commonly used to estimate anaerobic power are: oxygen debt, oxygen deficit, concentration of lactic acid in the blood or in the muscle, the Sargent jump, and the Margaria step test (Ayalon, Inbar & Bar-Or, 1974).

Improvements in anaerobic power following training are mainly attributed to increases in the ATP-CP concentration in the muscle (Karlsson, Nordesjö, Jorfeldt, & Saltin, 1972) and increases in the oxygen debt and blood lactate concentration (Cunningham & Faulkner, 1969) that the individual is able to tolerate due to increases in the alkaline reserves (Mathews & Fox, 1976). In addition, training causes an increase in key enzymes that control glycolysis, (Gollnick, Armstrong, Saltin, Saubert, Sembrovich & Shephard, 1973).

Gollnick et al (1973) reported that the activity of one key enzyme, phosphofructokinase (PFK), which is important in the early reactions of glycolysis, doubled following five months of bicycle ergometer training. Erikson, Gollnick and Saltin (1973) reported an 83 percent increase in PFK activity following training. Other important glycolytic enzymes have also been reported to increase following physical training

(Baldwin, Winder, Terjung & Holloszy, 1972; and Staudte, Exner & Pette, 1973).

Cunningham and Faulkner (1969) studied the effect of training on aerobic and anaerobic metabolism during a short exhaustive run in eight males before and after training. The short exhaustive run was performed on a treadmill at a speed of eight miles/hour and a grade of 20%. Run times ranged from 36 to 66 seconds. A six week training program of interval sprints of 220 yards and distance runs of two miles were utilized to stress the capacity of both aerobic and anaerobic metabolism. The training program resulted in a 23% increase in run time for the short exhaustive run. In comparing pre- to post-training results, a nine percent increase was evident in oxygen debt and a 17% increase in blood lactate concentration. The extra energy needed for the longer post-training run was attributed to increased glycolysis, and to an increased capacity to incur an oxygen debt.

Karlsson et al (1972) studied muscle lactate, ATP, and CP levels before and after three and seven months of physical training on 14 male subjects. Physical training the first three months consisted of running five to six kilometers as fast as possible three times/week. During the last four months of training the runs were repeated twice/ week. Muscle biopsies were taken before, after three and seven months of training, during rest, and after submaximal and maximal work loads, on which determinations of muscle ATP, CP, glycogen, and lactate concentrations were performed. The conditioning program increased the resting ATP concentration in the muscle, while CP concentration was unaffected. Less pronounced phosphogen (ATP-CP) depletion was found at the same submaximal work load following training and muscle lactate concentration was significantly lower at the same absolute and relative submaximal work load. At maximal work, lactate concentration was not increased.

The lower lactate production at the same submaximal work load after the training was partly explained by a lower oxygen deficit and by a faster oxidative metabolism of the lactate produced.

Schreiber (1973) investigated anaerobic power as a function of somatotype and participation in varsity athletics. Fifty-two male varsity athletes who represented soccer, football, basketball, gymnastics, cross-country running and wrestling served as subjects. A Margaria-Kalman test was administered for anaerobic power before and after eight weeks training in their sport specialty.

Results indicated that there were significant variations among given athlete specialties. Cross-country runners ranked lowest with an average power output of 100.5 kg-m/sec, compared to an average power output of 193.7 kg-m/sec for the wrestlers. Post-training results revealed that anaerobic power attributed to the ATP-CP metabolic source was improved through participation in football, soccer, wrestling, gymnastics and cross-country running. The basketball representatives showed a slight decrease in anaerobic power following training. Post-training lactate levels following a short exhaustive run increased among all athletic specialties, with the exception of basketball.

Coleman, Kreuzer, Friedrick and Juvenal (1974) investigated aerobic and anaerobic power of male college freshmen during a season of basketball. Nine freshmen basketball players who had been awarded an athletic scholarship for basketball ability served as subjects. Following a 21 week competitive schedule a Margaria-Kalman test was re-administered to test for anaerobic power. No significant differences were found in anaerobic power following training.

Katch et al (1977) conducted two separate experiments to ascertain the optimum protocol for a maximum anaerobic work output test on the bicycle ergometer. The first experiment was designed to determine the revolution rate and time duration, while the second determined the optimum frictional resistance. Their results indicated that the optimum characteristics for a bicycle ergometer anaerobic test were that the duration need be only approximately 40 seconds and the optimal frictional resistance, 5 to 6 Kp, with an all-out pedal frequency.

Physical Working Capacity (170)

Physical working capacity is often defined as the maximum intensity and/or duration of work a person can accomplish. The rate of work on a bicycle ergometer which stimulates a steady state heart rate of 170 beats/min is one commonly used submaximal indicator of physical performance. Borg and Linderholm (1967) indicated that measurements of perceived exertion during submaximal work on a bicycle ergometer (for example, work rate 170 beats/min) are good indicators of performance capacity. Sinning (1975) indicated that in the PWC test the relationships between heart rate, oxygen consumption, and work output are utilized to evaluate cardiovascular-respiratory fitness.

Frick et al (1970) investigated the effect of two months of physical training on cardiovascular dimensions of 20 normal males aged 18 to 19 years. The basic daily physical activity over the experimental period consisted of a 500 meter run at submaximal speed and one-half hour of short spurts at maximal speed. Once a week the subjects marched 15 kilometers at a speed of five kilometers/hour. Changes in cardiovascular dimensions were explored by measuring the heart volume from biplane chest X-rays, the blood volume by human albumin ^{131}I, and left ventricular wall thickness by ultrasound. Each subject performed a PWC_{170} test pre- and post-training. The two months of training increased PWC_{170} significantly ($p < .001$) from 1044 to 1177 kpm/min following training. Heart and blood volumes remained essentially unchanged.

In attempting to determine the effect of interaction of frequency and intensity of training on PWC_{170}, cardiovascular function and body composition, Crews and Roberts (1971) studied 43 sedentary male subjects before and after undergoing seven weeks of physical training. Subjects were tested and then randomly assigned to one of six training groups, at three levels of frequency (5, 3, or 1 day/week), and two levels of intensity (exercise heart rates of 150 and 120 beats/min). Each subject exercised a total of 50 minutes/week at his designated intensity. Results indicated that there were no significant differences between five and three day groups. All groups improved significantly ($p < .05$) in PWC_{170}. The 150 heart rate group made a significantly greater mean increase than the 120 beats/min group. All groups showed a decrease in exercise and recovery heart rate. It was concluded that frequency and intensity of training do not interact to produce significantly different training changes. While both intensity groups did show improved responses to the PWC test, the 150 heart rate group produced a superior training effect to the 120 heart rate group. Training five or three days/week was found to be superior to training only one day/week with regard to increasing PWC_{170}. Similar results in regards to improvement in PWC_{170} have been reported by Hill (1969), and Jackson, Sharkey and Johnson (1968).

Giesielievich (1974) studied PWC_{170} of wrestlers ranging in age from 8 to 35 years and in weight from 48 to over 100 kg. The results indicate that up to the age group of 11 - 12 years, PWC_{170} of the young wrestlers corresponds to the indices characteristic of healthy untrained adolescents. A sudden leap in PWC_{170} was noted in the wrestlers at age 15 - 16. The sudden leap was explained in terms of puberty and the beginning of pre-season conditioning. Giesielievich (1974) reported PWC_{170} indices of experienced 20 - 35 year-old wrestlers to range from 17.10 to 21.08 kpm/min/kg with a mean value of 19.70 kpm/min/kg. It was noted that the wrestlers taking part in the lighter weight categories (48, 52, 67, 62 & 68 kg) had the largest PWC_{170} indices.

Ribisl and Herbert (1970) investigated PWC_{170} of eight wrestlers under three conditions; a) in the normal state; b) after a five percent weight loss within 48 hours; and c) after five hours of rehydration. PWC_{170} for the group was reported at 1175 kpm/min in the normal state and 932 kpm/min in the dehydrated state.

Brouha (1962) stated that inborn capacity, sex, and age of the individual influence quantitatively the adaption processes to muscular activity and the maximum improvement that can be achieved by training. While investigating the effect of five weeks of controlled interval training on PWC_{170} and body composition, Watson and O'Donovan (1977) used 17 male subjects of diverse pre-training condition and ranging in age from 15 to 19 years. Four of the subjects were athletes and engaged in structured training regularly whereas the others were non-athletes and had not participated in any type of organized training.

Following the training period, the improvement in PWC_{170} was greater for the non-athletes (14.6%) than for the athletes (5.3%). In comparing athletes to non-athletes, the athletes had higher PWC_{170} values when expressed in both kpm/min and kpm/min/kg (1036 compared to 966 kpm/min and 15.69 compared to 15.24 kpm/kg/min), respectively. It was concluded that the magnitude of the change in PWC occurring as a result of training is primarily dependent upon the initial value.

Similar results for PWC_{170} were reported by Frick, Konttinen and Sarajus (1963) in the investigation of the effects of physical training on circulation at rest and during exercise. Fourteen men with sedentary habits, aged 19 to 26, were studied just before and after two months of hard basic military training. The physical working capacity (PWC_{170}) was determined by a bicycle ergometer as the work in kpm/min at a pulse of 170 beats/min. The initial PWC_{170} ranged from 720 to 1332 kpm/min, with a mean of 959 kpm/min. After the training, increased values were observed in 10 cases, unchanged values in three, and a slight decrease in one case; which had a high value initially. The mean increment was 113 kpm/min, averaging 12% ($\underline{p} < .01$).

In an assessment of the cardiovascular fitness of sportsmen, Watson (1978) used 18 first-year and 19 second-year specialist students of physical education, aged respectively 18.29 and 19.03 years. Subjects performed a twelve-minute run-walk test and a PWC_{170} test. The twelve-minute run-walk scores were significantly related to PWC_{170} in the case of the second-year students and when both groups were combined, but not in the case of the first-year group. PWC_{170} scores were 1112.0 and 1140.0 kpm/min for the first-year group and second-year group, respectively.

Although the literature is quite limited in comparing one athletic group to another, the available literature indicates that the wrestler has a higher PWC_{170} than the untrained and the moderately trained individual.

<u>The effects of training on resting, recovery and maximal heart rate</u>

The literature is replete with studies testifying to the effects of exercise upon various components of the cardiovascular system. Results of a study by Knehr, Dill and Neufeld (1942) showed decreases of five beats per minute in both the resting pulse rate and submaximal exercise pulse rates of men following a six-months exercise program. Skinner, Hollszy and Cureton (1964) employing a variety of endurance exercises, found a decrease in mean heart rates of approximately 10 beats/min at each work load studied.

There are numerous studies which have explored the contributions of various specific exercise programs to the development and/or maintenance of cardiovascular efficiency. Wallin and Schendel (1969) concluded that 10 weeks of participation in a systematic jogging program would produce reduction in the heart rates of middle-aged men at submaximal exercise. Shaver (1974a) reported a significant decrease in resting heart rate (10 beats/min) following a season of wrestling training. In addition, he reported a significant decrease in exercise heart rate at a submaximal work load and a significant decrease in recovery heart rate. However, Frick et al (1970) reported that subjects undergoing two hours of moderate physical training over a period of two months failed to show any changes in the resting heart rate.

Early studies by Christenson (1931) and Hoogerwerf (1929) pointed out that individuals with high levels of cardiovascular endurance usually have low resting heart rates, and that regular training with a given standard work load would gradually lower the exercise heart rate. Hoogerwerf (1929) found a mean pulse of 50 beats/min in 260 athletes participating in the Amsterdam Olympic Games (1928), the lowest value being 28 beats/min in one cross-country skier.

The studies by Davies, Tuxworth and Young (1970), Hanson & Tabakin (1965), Durnin, Brockway and Whitcher (1960), Shaver (1974a), Hartley et al (1969), Karvonen, Kentala, Mustala (1957), and Knehr et al (1942) have showed that resting and submaximal exercise heart rate can be decreased following a training program. A reduction in maximal heart rate following training has not as yet been unequivocally resolved. Several authors (Davies et al 1970; Ribisl, 1969; Blomquist, Mitchell, Johnson, Wildenthal & Chapman, 1968; Seigal, Blomquist & Mitchell, 1970) reported that a change in maximal heart rate was not evident following periods of training. Other investigators (Ekblom et al, 1968; Hartley et al, 1969; Pollock, Cureton & Greninger, 1969; Saltin, Hartley, Kilbom & Åstrand, 1969; Magel, Foglia, McArdle, Gutin, Pechar & Katch, 1974; Pechar, McArdle, Katch, Magel & Delucca, 1974; and Rowell, 1974) have reported that physical training results in a lower maximal heart rate.

It is apparent from these studies that the initial maximal heart rate, age, duration, and intensity of training that the subjects undergo are of prime considerations. Åstrand (1977) indicated that a reduction in maximal heart rate is more likely to be found following an endurance training program when the initial maximal heart rate is above 180 beats/min.

Mathews and Fox (1976) indicated that the resting bradycardia resulting from training is a) most evident when athletic and non-athletic subject are compared; b) less evident but still clear-cut when sedentary subjects undergo a training program; and c) least distinct when athletes are studied in the untrained versus the trained state.

Pollock et al (1969) trained 19 sedentary men (mean age 32.5) for either two times per week or four times per week for 20 weeks. Exercise sessions were 30 minutes in duration and consisted of continuous walking, running or jogging. Maximal heart rate decreased significantly (p ,05) over the first 10 weeks (from 187.8 to 180.2

beats/min) for the group training four times per week. The group training twice per week showed similar results after 20 weeks of training. Similar findings were reported by Ekblom et al (1968) using 10 healthy male subjects (aged 19 to 27) and training them with a cross-country endurance type program for 16 weeks. Significant decreases in heart rate (13 beats/min) were reported at a submaximal work load and in maximal heart rate (200 to 192 beats/min) were found following the program.

In investigating maximal heart rates and $\dot{V}O_2$ max of long distance runners and other athletes, Koeslag and Sloan (1976) found that long distance runners had lower maximal heart rates than swimmers, oarsmen, squash, badminton and rugby football players (182 compared to 194 beats/min).

Mathews and Fox (1976) distinguished between the endurance trained heart and the non-endurance trained heart by illustrating that the cardiac hypertrophy of endurance athletes is characterized by a larger ventricular cavity, thus a greater stroke volume, and a normal thickness of the ventricular wall, whereas, the cardiac hypertrophy of the non-endurance athlete, that is, athletes engaged in high resistance or isometric types of activities such as wrestling and football, is characterized by a normal-sized ventricular cavity and a thicker ventricular wall. Additionally, Mathews and Fox (1976) indicated that a reduction in maximal heart rate and a lowering of the resting heart rate is the result of many years of hard endurance training.

Parnat et al (1975) reported maximal heart rates of athletes (N=95) engaged in various sporting events. The swimmers (N=12) had the highest maximal heart rate of 200 beats/min, followed by the cyclists (197 beats/min), and decathlonists (195.7 beats/min). The cross-country skiers, runners and volleyball players ranked third with maximal heart rates of 183 beats/min. The basketball players (N=14) had the lowest maximal heart rates (166 beats/min).

While investigating the effect of a season of ice hockey on energy capacities and associated functions of two elite junior ice hockey teams, Green and Houston (1975) found no change in maximal heart rate following five months of training. The mean pre-training maximal heart rate was 191.6 beats/min. Similar findings have been reported by Kelly et al (1978) in their investigation of the effect of five months of varsity wrestling on various physiological parameters. Mean maximal heart rates of 192 beats/min before training and 193 beats/min following training were reported.

In a physiological evaluation of 18 professional soccer players, Raven, Gettman, Pollock and Cooper (1977) reported mean resting heart rates of 50 beats/min and mean maximal heart rates of 188 beats/min. Similar maximal heart rate values have been reported by Maksud, Wiley, Hamilton and Lockhart (1970) in their investigation of Olympic speed skating candidates and by Saltin and Åstrand (1967) in their analysis of Swedish national team members.

Fahey et al (1975) reported mean maximal heart rates of 185.4 beats/min for 30 exceptional weight trained athletes. The wrestlers (N=2) had the highest mean maximal heart rate of 192.2 beats/min.

Reilly and Thomas (1977) reported that six weeks of pre-season soccer training produced a significant decrease in resting heart rate (65.0 to 54.0 beats/min) and a significant decrease in submaximal exercise heart rates (158 to 132 beats/min). A slight reduction in maximal heart rate was apparent, however it was not significant (198 to 196 beats/min).

There appears little doubt that physical training is beneficial to the individual in terms of increasing cardiovascular efficiency. The initial level of fitness, age, duration and intensity of training are prime features that govern changes in the cardiovascular system. The available literature supports the hypothesis that a more efficient cardiovascular system will enable better performances.

Chapter 3

METHODOLOGY

Research Design

Bi-weekly and monthly repetitive testing sessions were used to investigate the effect of seasonal wrestling training and unavoidable interventions on $\dot{V}O_2$ max, anaerobic power, PWC_{170}, resting and maximal and recovery heart rate of the wrestler.

Subjects

Subjects used in this study were potential varsity team wrestlers ranging in age from 18 to 24 years (the characteristics of subjects are shown in Table 1).

Investigative Period

The investigative period for this study extended over 18 weeks, commencing October 30, 1978 and terminated March 3, 1979.

Training Schedule

Subjects underwent 18 weeks of typical wrestling training. (see Appendix A for typical training session) Training sessions were approximately two hours in duration and five times/week. Most of the subjects participated in competition against Canadian and American wrestlers on ten weekends. Commencing January 10, 1979, subjects were required to take part in two training sessions/day. The morning session stressed that the wrestlers work on their weaknesses, for example; strength, technique or cardiovascular conditioning, whereas, the evening session was similar to that outlined in Appendix A.

Table 1

Characteristics of Subjects

Subject	Age (yr)	Height (cm)	Weight (kg)
*MS	19	169	58.1
**AD	22	165	60.4
PJ	18	170	65.3
**CN	23	164	67.1
DA	19	171	70.0
***LH	20	175	70.7
SR	24	170	72.2
**CP	22	175	76.1
WM	18	171	77.5
***BR	23	177	77.5
*TJ	19	178	77.9
Mean	20.6	171.4	70.3
Range	18 - 24	164 - 168	58.1 - 77.9

Note: * Indicates number of matches that were won at the College championships.

Testing Schedule

Each subject underwent bi-weekly testing for anaerobic power and physical working capacity (170). A three week period elapsed between tests four and five because most subjects left the university campus for this duration. Resting heart rate, maximum oxygen uptake, and maximal heart rate were tested monthly during the first Saturday and Sunday of each investigated month between 11:00 a.m. and 3:00 p.m.

Once the academic schedules were received, each subject was assigned to one of three days to be tested bi-weekly for anaerobic power, PWC_{170}, and recovery heart rate. The test days were Tuesday, Wednesday and Thursday at 3:30 p.m. Anaerobic power was tested the following day at 4:30 p.m. Once the testing schedule had been established each subject was tested at the same time each testing session.

Testing Procedure

For all testing sessions subjects were asked to report to the human performance laboratory in the C.J. Sanders building wearing shorts and running shoes. The subjects were instructed to avoid vigorous activity for at least twelve hours before testing and to refrain from eating, taking medication, or drinking anything except water for the two hours prior to testing. Each subject's age, weight and height was recorded upon arrival at the laboratory. A Toledo balance scale was used to measure weight to the nearest one-tenth of a kilogram and height to the nearest centimeter.

Resting Heart Rate

A cardiometer Model AB was used to determine resting heart rate with the subjects lying down in the supine position. Subjects were covered with a blanket and instructed to avoid talking and to restrict their movement as much as possible for a 20 minute period. At the end of the 20 minute period the resting heart rate was recorded.

PWC_{170} and Five Minute Recovery Heart Rate (RHR sub)

In this study PWC_{170} was determined following the technique and procedure outlined by Wahlund (1948).

The general protocol of the test required each subject to perform steady-state exercise on a bicycle ergometer at increasing work loads. Subjects performed a total of 12 minutes of work which was divided into two six minute working sessions. The first work load was aimed at producing a heart rate in the range of 120 to 130 beats/min at the fifth minute, while the second work load was aimed at producing a heart rate in the range of 160 to 170 beats/min at the eleventh minute.

Upon completion of the second work load the subjects continued pedalling at 50 RPM without any work load for one minute. At the end of one minute, subjects stopped pedalling and remained seated on the bicycle ergometer for the next four minutes. At the end of the fourth minute the heart rate was recorded.

Maximum Oxygen Uptake ($\dot{V}O_2$ max)

A modified version of the test protocol developed by Saltin and

Åstrand (1967) was used to measure $\dot{V}O_2$ max on a Quinton treadmill Model 18-60B.

The treadmill speed was set at six miles/hour (161 meters/min) and zero percent grade. The grade was increased two percent at every minute for five minutes. The grade was further increased two percent every five minutes thereafter until the subject was no longer able to keep up to the speed of the treadmill. Heart rate was continuously monitored using a cardiometer Model AB. A one minute sample of expired air was collected into a chain-compensated Gasometer Model 2558 when the subject approached the pre-determined maximal heart rate. The subjects were under visual observation throughout the entire exercise period and upon showing signs of fatigue (having difficulty keeping up to the treadmill speed) the subjects were strongly encouraged to continue running and a second one minute sample of expired air was collected.

Subjects wore a head gear which was attached to a mouthpiece (Rudolph valve #2700) which allowed subjects to breathe in room air and expire only into a chain-compensated Gasometer Model No. 2558 via flexible hosing.

Gas Analysis

Expired air samples were analyzed for percent CO_2 and O_2 with an Infra Red Gas analyzer and a Taylor Servomax analyzer (Model OA 202), respectively. Analyzers were calibrated at the beginning of each test session with reference gases which were verified with the Micro Scholander gas analyzer.

Five Minute Recovery Heart Rate Following Maximum Effort (RHR sub)

Once the subject was forced to stop running because of fatigue the maximal heart rate was recorded. The speed and grade of the treadmill was then reduced to 3.5 miles/hour and zero percent grade. Subjects were instructed to continue running at this reduced intensity for one minute to reduce the risk of possible injury and ill feelings (Cooper 1977). The subject then laid down on a mat situated beside the treadmill for the next four minutes. At the end of the fourth minute the recovery heart rate was recorded.

Anaerobic Power

Anaerobic power was determined according to a modified version of the test protocol developed by Katch, Weltman, Martin and Gray (1977). Subjects pedalled the bicycle ergometer at the work load of 5.5 kp for 40 seconds. Subjects were not required to sit on the seat of the bicycle ergometer.

Analysis of Data

Data obtained from the tests were analyzed utilizing SPSS (The Statistical Package for the Social Sciences) at the Lakehead University computing centre. The data were analyzed by one-way analysis of variance and a Tukey Test was applied to judge appropriate contrasts.

Chapter 4

RESULTS

Characteristics of subjects are presented in Table 1. The means, standard deviations, ranges, and F-ratio's are shown in Tables 2 and 3, and the mean and percentage differences of each variable are shown in Tables 4 to 15. Figures 1 to 12 illustrate the test responses of each variable.

The weight of the subjects demonstrated small bidirectional changes over the training program. The mean pre-training weight (T_1) of 70.3 kg was not significantly different from the mean post-training weight (T_9) of 68.7 kg.

In the resting heart rate, the Tukey value indicated that the resting heart rate of 47.5 beats/min (T_5), was significantly ($p < .05$) lower than that of T_1 and T_3 of 51.2 and 52.5 beats/min, respectively (see Table 4 & Figure 1).

As can be seen in Table 5, differences were apparent for maximal heart rate over the training program, however, the differences failed to reach statistical significance. The similar trend was also found in the five minute recovery heart rate following maximum effort (RHR max) and anaerobic power.

Maximum oxygen uptake ($\dot{V}O_2$ max) showed significant ($p < .05$) improvement over the training program in both L/min and ml/kg/min. The $\dot{V}O_2$ max of T_5 was significantly greater than that of T_1 and T_3. Tables 8 and 9 indicate that the differences between T_1 and T_5 and between T_3 and T_5 to be a 7.8% and 9.3% increase in aerobic power, respectively. A non-significant decrease of 4.2% was found between

Table 2

Means, Standard Deviations, Ranges and F-ratio's for Weight, Resting and Maximal and Recovery Heart Rate, Maximum Oxygen uptake and Ventilation

Test No	Variables / Statistics	Weight (kg)	Resting HR (beats/min)	Maximal HR (beats/min)
	Mean	70.3	51.27	191.2
	S.D.	7.0	6.0	10.4
	Range	58.1 - 77.9	42 - 66	175 - 209
	Mean	69.8	51.0	192.0
2	S.D.	7.1	5.7	11.0
	Range	56.7 - 78.1	41 - 60	180 - 214
	Mean	69.9	52.54	195.5
3	S.D.	7.5	4.0	12.9
	Range	54.7 - 78.7	45 - 60	177 - 218
	Mean	69.9	50.81	194.4
4	S.D.	7.2	5.0	13.6
	Range	56.3 - 78.7	42 - 57	177 - 222
	Mean	68.7	47.5	193.4
5	S.D.	8.3	3.5	9.8
	Range	51.4 - 78.6	42 - 51	177 - 205
F-ratio		.04	1.07	.25

$^*p < .05$

Table 2--continued

RHR max (beats/min)	$\dot{V}O_2$ max L/min	$\dot{V}O_2$ max ml/kg/min	$\dot{V}_E$ (L/min)
98.7	4.37	62.1	115.9
11.6	.28	4.5	13.9
80 - 115	4.00 - 4.82	54.8 - 68.4	91.3 - 133.3
99.6	4.50	65.3	110.6
9.7	.26	5.5	7.9
82 - 112	4.09 - 4.95	57.4 - 72.3	96.1 - 124.2
100.5	4.31	62.2	115.5
10.7	.29	6.2	15.4
84 - 116	3.84 - 4.70	50.8 - 70.2	99.9 - 146.4
100.3	4.56	65.7	124.0
11.3	.34	5.3	10.6
85 - 123	3.86 - 5.03	58.2 - 72.7	100.0 - 133.6
95.9	4.71	69.0	125.4
9.8	.39	5.6	15.2
70 - 111	4.09 - 5.12	60.7 - 80.1	104.1 - 132.1
.34	2.77*	3.01*	2.56*

T_2 and T_3 (period of unavoidable interventions). The $\dot{V}O_2$ max immediately following the intervention period (T_3) were similar to the pre-training value (T_2) (see Figure 4 and 5). A similar trend was also found in the PWC_{170}, anaerobic power, resting and maximal heart rate, heart rate after 12 minutes of submaximal work, RHR max and RHR sub.

Expired volumes ($\dot{V}_E$) revealed a significant $\underline{F}$-ratio (2.56) and significant increases ($\underline{p} < .05$) were found. The T_5 value was significantly greater than all other test means with the exception of T_4. The T_4 value was only significantly greater than the T_2 value (see Table 5).

Physical working capacity 170 (PWC_{170}) failed to show significant improvement following 18 weeks of wrestling training when expressed in kpm/min. Test five (T_5) yielded the lowest PWC_{170} (1355 kpm/min and 19.5 kpn/min/kg), whereas, T_9 yielded the highest PWC_{170} (1525 kpm/min and 22.1 kpm/min/kg). As can be seen in Tables 12 and 13 the difference between the highest and the lowest PWC_{170} was 170 kpm/min of 12.5%. The T_5 value of 1355 kpm/min represents a non-significant decrease of 5.6% from the T_1 value and a 3.5% decrease from T_4. A significant improvement ($\underline{p} < .05$) of 13.3% was found between T_5 and T_9 when PWC_{170} was expressed in kpm/min/kg.

The T_5 heart rate after 12 minutes of submaximal work was significantly ($\underline{p} < .05$) greater than all other test means with the exception of T_4. The T_4 value was only significantly greater than T_9 (see table 10 & Figure 7). The five minute recovery heart rate

Table 3

Means, Standard Deviations, Ranges and *F*-ratio's for Weight, Physical Working Capacity 170, 12 Minute Heart Rate, Recovery Heart Rate following submaximal work and Anaerobic Power

Test No	Statistics \ Variables	Weight (kg)	PWC_{170} kpm/min	PWC_{170} kpm/min/kg
1	Mean	70.3	1435	20.3
	S.D.	7.0	284	3.3
	Range	58.1 - 77.9	936 - 1890	14.2 - 26.7
2	Mean	70.1	1446	20.6
	S.D.	7.3	288	3.2
	Range	57.1 - 78.8	900 - 1950	15.8 - 27.3
3	Mean	69.8	1456	20.8
	S.D.	7.1	338	3.7
	Range	56.7 - 78.1	907 - 2040	16.0 - 28.5
4	Mean	69.0	1406	20.1
	S.D.	7.1	245	3.0
	Range	57.0 - 78.1	1015 - 1852	15.4 - 25.9
5	Mean	69.8	1355	19.5
	S.D.	7.5	210	2.7
	Range	54.9 - 78.7	999 - 1675	15.4 - 24.1
6	Mean	69.5	1462	21.0
	S.D.	7.5	281	3.4
	Range	55.0 - 78.6	969 - 2045	17.1 - 28.0
	Mean	69.6	1446	20.7
	S.D.	7.2	240	2.7
	Range	56.3 - 78.7	987 - 1845	17.5 - 25.7
8	Mean	69.6	1482	21.2
	S.D.	7.5	285	3.1
	Range	54.6 - 78.0	1004 - 1995	18.1 - 27.9
9	Mean	68.7	1525	22.1
	S.D.	8.3	285	2.6
	Range	51.4 - 78.6	1005 - 1990	18.6 - 28.3
F-ratio		.04	.33	.64

$^{*}p < .05$

Table 3--continued

12 Minute Heart Rate (beats/min)	RHR sub (beats/min)	Anaerobic Power (kpm/40sec)	(kpm/40sec/kg)
161.4 9.8 150 - 184	91.2 7.2 80 - 105	2253 203 1980 - 2574	31.9 2.3 25.9 - 34.6
159.8 7.4 147 - 171	83.7 6.1 75 - 92	2235 166 1980 - 2475	32.1 2.3 27.2 - 35.8
161.1 9.0 147 - 174	85.0 7.6 75 - 97	2286 216 2013 - 2706	32.9 2.4 27.1 - 35.5
163.8 8.0 149 - 174	84.8 10.0 70 - 98	2242 219 1882 - 2607	32.2 2.7 25.1 - 35.5
167.6 8.4 156 - 180	90.6 11.4 68 - 102	2195 213 1914 - 2574	31.5 2.4 26.4 - 36.0
161.5 7.6 148 - 172	85.3 11.3 63 - 98	2232 248 1782 - 2574	32.2 2.4 26.9 - 34.8
160.4 6.3 149 - 170	83.4 7.3 71 - 92	2253 224 1914 - 2607	32.4 2.2 26.9 - 35.1
159.4 9.3 145 - 176	80.3 8.7 64 - 95	2274 210 1944 - 2636	32.8 2.4 27.2 - 35.6
156.4 8.3 145 - 168	75.5 8.5 60 - 87	2249 232 1845 - 2609	32.9 2.5 26.9 - 35.9
1.56*	3.24*	.16	.43

(RHR sub) for T_9 was significantly ($p < .05$) lower than all other test means with the exception of T_3, T_5 and T_6. An increase of 5.8 beats/min was evident between T_4 and T_5 (see Table 11).

Anaerobic power was not changed significantly by 18 weeks of wrestling training or by the unavoidable interventions. The lowest anaerobic power value of 2195 kpm/40sec was exhibited for T_5, whereas, the greatest anaerobic power (2274 kpm/40sec) was found for T_3. The difference between T_5 and T_3 of 79 kpm/40sec failed to reach the significant difference of 152 kpm/40sec. As can be seen in Figure 11, the greatest anaerobic power was exhibited in T_3 when expressed in kpm/40sec, however, when expressed per kg of body weight anaerobic power was greater in T_9 (see Figure 12).

The most favourable values for $\dot{V}O_2$ max, PWC_{170}, heart rate after 12 minutes of submaximal work, RHR sub, RHR max and resting heart rate were found during the final testing session. Anaerobic power in kpm/40sec was greatest in T_3 and in kpm/40sec/kg was greatest in T_9. The test values immediately following the interventions were less favourable than the pre-training (T_1) scores in all variables with the exception of weight and RHR sub.

Table 4

Mean and percentage differences for resting heart rate (beats/min)

Percentage Difference

	Test No.	1	2	3	4	5
Mean Difference	1	——	.5	2.5	.9	7.5
	2	.27	——	3.0	.4	6.9
	3	+ 1.27	+ 1.54	——	3.2	9.5
	4	.46	.19	- 1.73	——	6.5
	5	- 3.82*	- 3.50*	- 5.09*	- 3.36	——

Tukey value at 0.05 level = 3.47*

Table 5

Mean and percentage differences for expired volumes ($\dot{V}_E$)

Percentage Difference

	Test No.	1	2	3	4	5
Mean Difference	1	——	4.6	.4	7.0	8.2
	2	- 5.35	——	4.4	12.1	13.4
	3	.40	+ 4.94	——	7.4	8.6
	4	+ 8.05	+13.40*	+ 8.45	——	1.1
	5	+ 9.43*	+14.78*	+ 9.87*	+ 1.38	——

Tukey value at 0.05 level = 9.12*

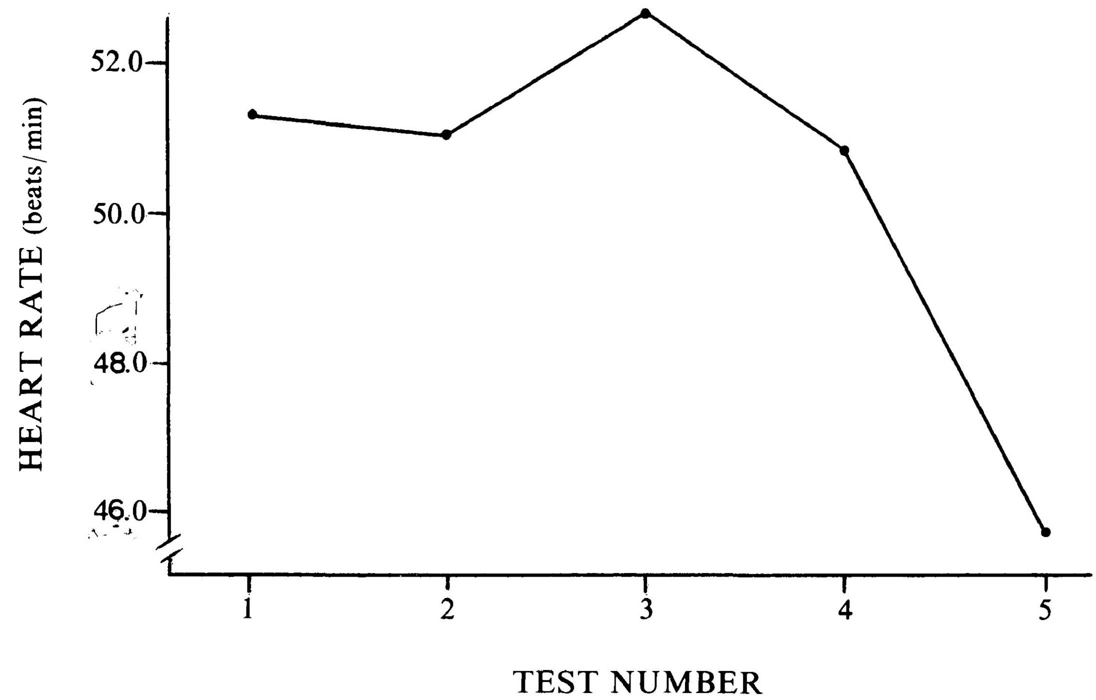

Figure 1: Mean resting heart rate.

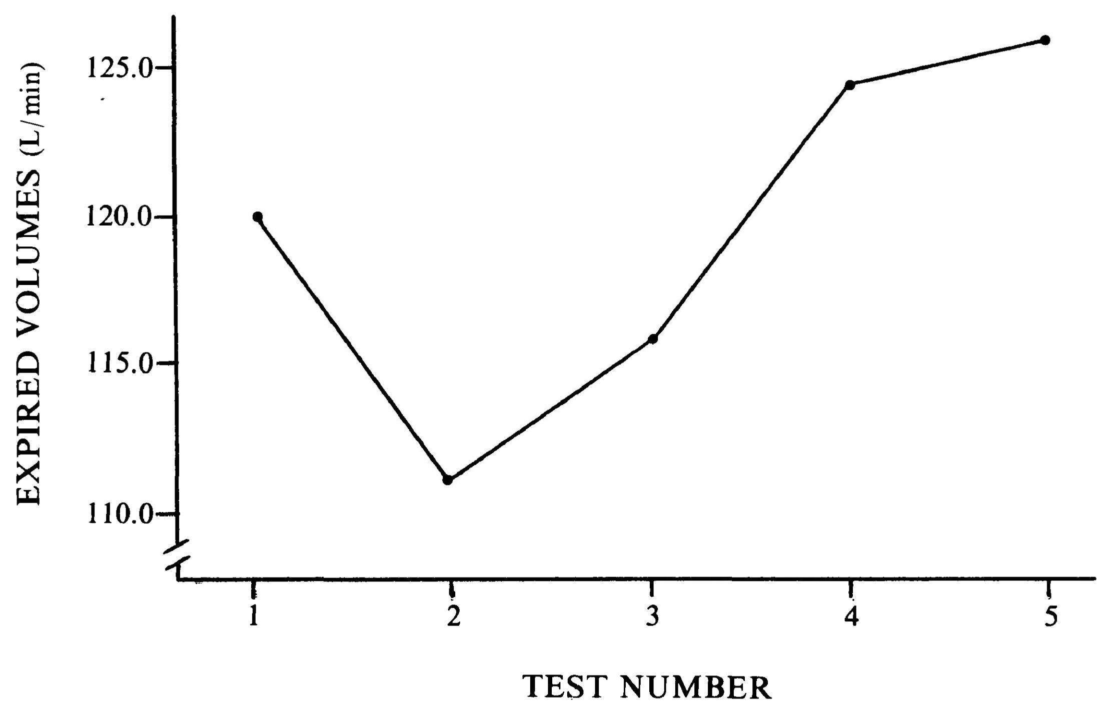

Figure 2: Mean expired volumes.

Table 6

Mean and percentage differences for the five minute recovery heart rate (RHR max)

Percentage Difference

Mean Difference — Test No.	1	2	3	4	5
1	——	.9	1.8	1.6	2.8
2	+ .91	——	.9	.7	3.7
3	+ 1.82	+ .91	——	.2	4.6
4	+ 1.55	+ .64	.67	——	4.4
5	- 2.82	- 3.73	- 4.64	- 4.37	——

Tukey value at 0.05 level = 7.53*

Table 7

Mean and percentage differences for maximal heart rate (beats/min)

Percentage Difference

Mean Difference — Test No.	1	2	3	4	5
1	——	.4	2.3	1.1	.6
2	+ .82	——	1.8	1.2	.7
3	+ 4.36	+ 3.54	——	.6	1.1
4	+ 2.18	+ 2.36	- 1.18	——	.5
5	+ 1.18	+ 1.36	- 2.18	- 1.0	——

Tukey value at 0.05 level = 8.23*

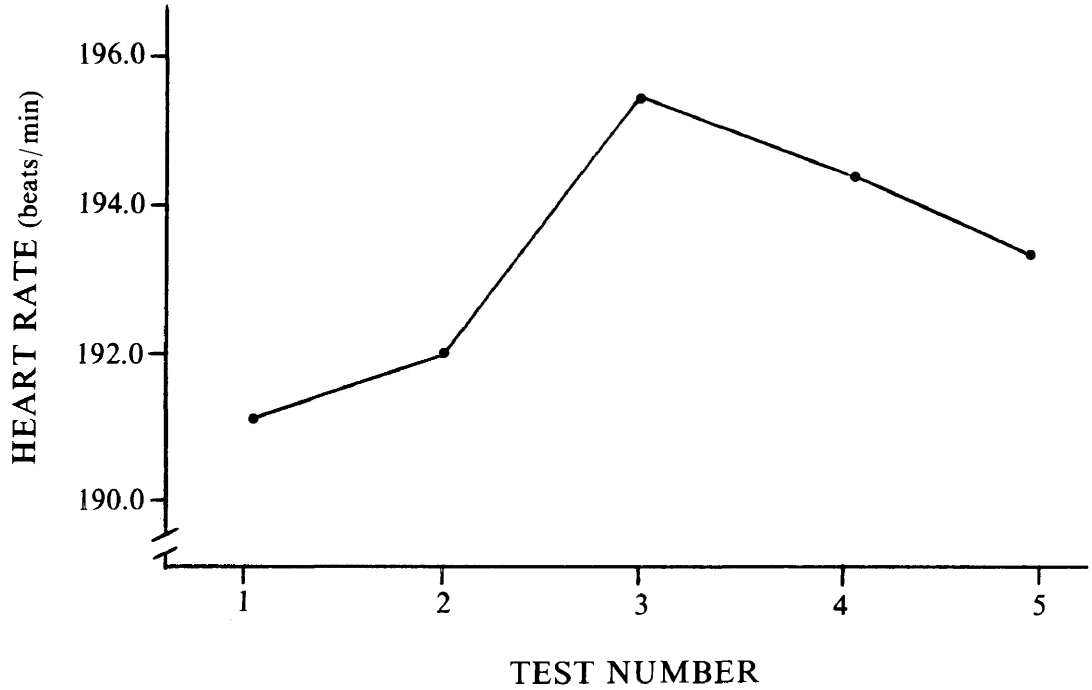

Figure 3: Mean maximal heart rate during maximal exercise.

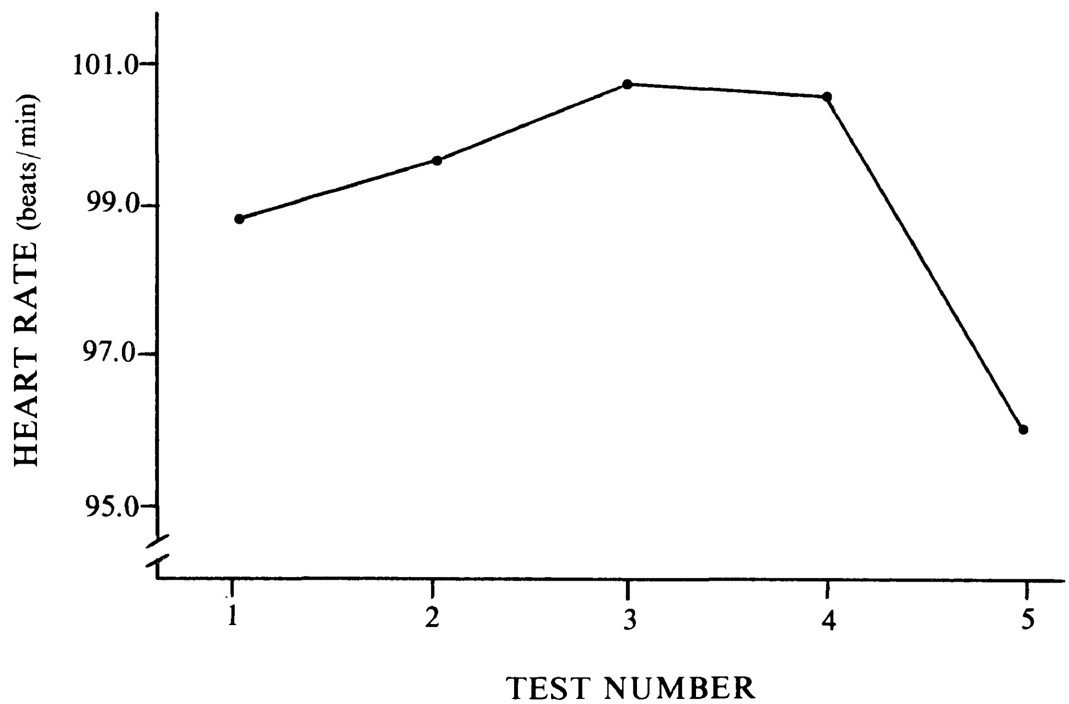

Figure 4: Mean five minute recovery heart rate after maximal exercise.

Table 8

Mean and percentage differences for $\dot{V}O_2$ max
(L/min)

Percentage Difference

Mean Difference — Test No.	1	2	3	4	5
1	—	.30	1.4	4.3	7.8
2	+ .13	—	4.2	1.3	4.7
3	.06	.19	—	5.8	9.3
4	+ .19	+ .06	+ .25*	—	3.3
5	+ .34*	+ .21	+ .40*	+ .15	—

Tukey value at 0.05 level = .22*

Table 9

Means and percentage differences for $\dot{V}O_2$ max
(ml/kg/min)

Percentage Difference

Mean Difference — Test No.	1	2	3	4	5
1	—	5.2	.2	5.8	11.1
2	+ 3.21	—	4.8	.6	5.7
3	.12	- 3.09	—	5.6	10.9
4	+ 3.66	+ .45	+ 3.45	—	5.0
5	+ 6.94*	+ 3.73	+ 6.82*	+ 3.28	—

Tukey value at 0.05 level = 3.86*

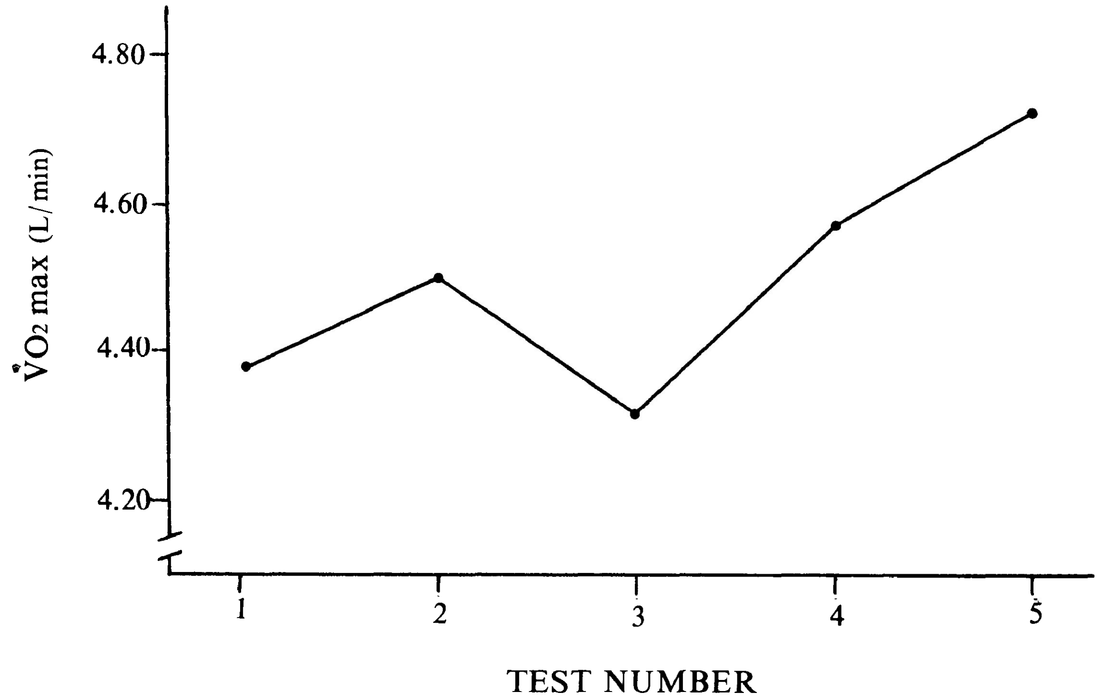

Figure 5: Mean values for maximum oxygen uptake in L/min.

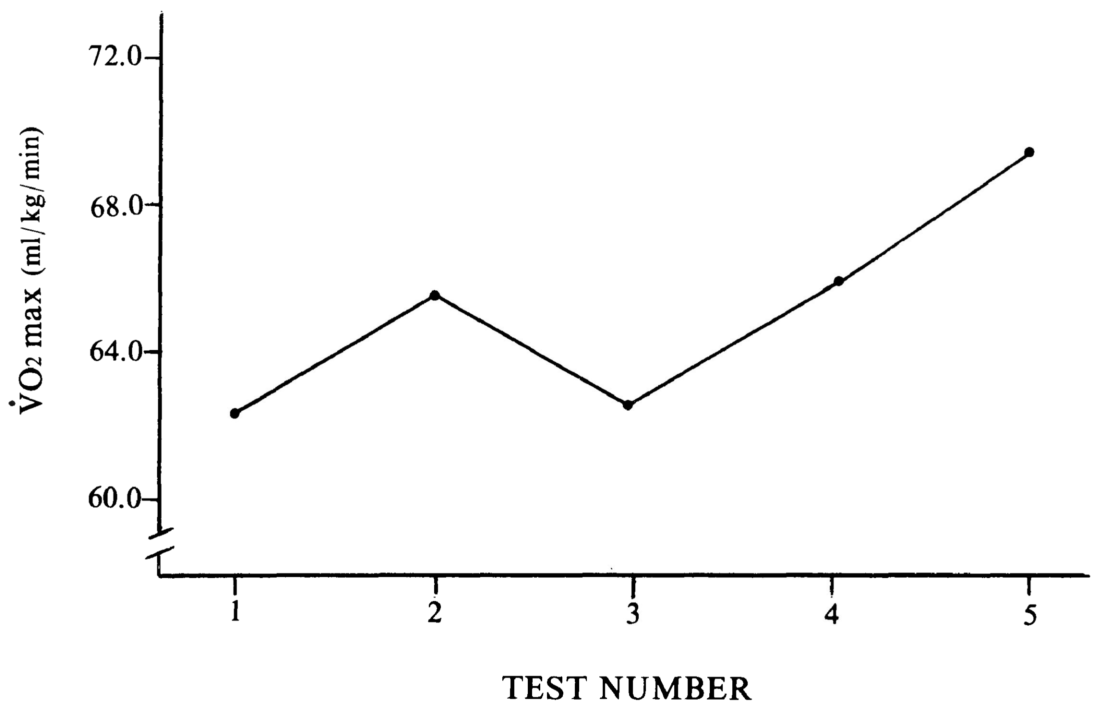

Figure 6: Mean values for maximum oxygen uptake in ml/kg/min.

Table 10

Mean and percentage differences for heart rate after
12 minutes of submaximal work (beats/min)

Percentage Difference

Test No.	1	2	3	4	5	6	7	8	9
1	—	1.0	.2	1.5	3.8	.1	.6	1.2	3.1
2	-1.55	—	.8	2.5	4.9	1.1	.4	.3	1.9
3	- .27	+1.28	—	1.7	4.0	.3	.4	1.1	2.9
4	+2.45	+4.00	+2.72	—	2.3	1.4	2.1	2.7	4.5
5	+6.27*	+7.82*	+6.54*	+3.82	—	3.6	4.3	4.9	6.7
6	+ .09	+1.64	+ .36	-2.36	-6.18*	—	.7	1.3	3.2
7	-1.00	+ .55	- .73	-3.45	-7.27*	-1.09	—	6.2	2.5
8	-2.00	- .45	-1.73	-4.45	-8.27*	-2.09	-1.00	—	1.9
9	-5.00	-3.45	-4.73	-7.45*	-11.27*	-5.09	-4.00	-3.00	—

Mean Difference

Tukey value at 0.05 level = 5.84*

Table 11

Mean and percentage differences for the five minute recovery heart rate (RHR sub)

Percentage Difference

Test No.	1	2	3	4	5	6	7	8	9
1	—	8.2	6.8	7.0	.7	6.5	8.6	12.0	17.2
2	-7.46*	—	1.6	1.3	8.2	1.9	.4	4.1	9.8
3	-6.18	+1.28	—	.2	6.6	.4	1.9	5.5	11.2
4	-6.37*	+1.09	- .19	—	6.9	.6	1.2	5.3	11.0
5	- .55	+6.91*	+5.63	+5.82	—	5.9	8.0	11.4	16.7
6	-5.91	+1.55	+ .27	- .46	-5.36	—	2.2	5.9	11.5
7	-7.82*	- .36	-2.64	-1.45	-7.27*	-1.91	—	3.7	9.5
8	-10.91*	-3.45	-4.73	-4.54	-10.36*	-5.00	-3.09	—	6.0
9	-15.73*	-7.08*	-9.55*	-9.36*	-15.18*	-9.82*	-7.91*	-4.82	—

Mean Difference

Tukey value at 0.05 level = 6.26*

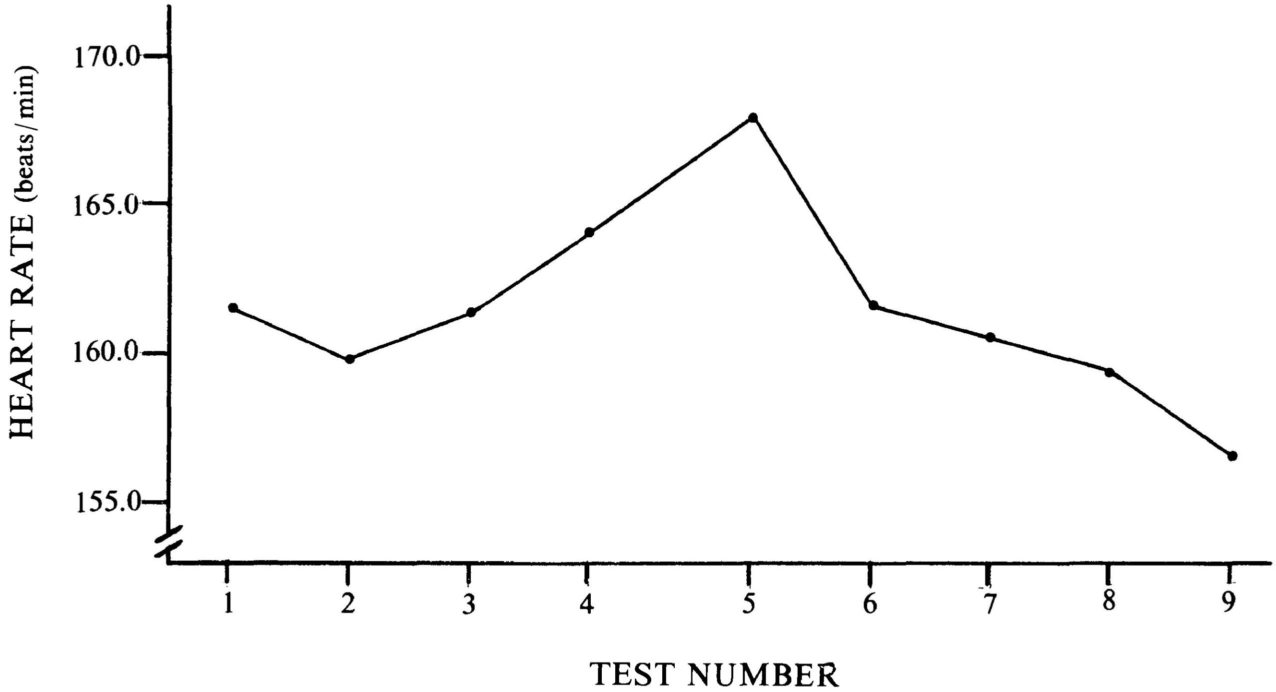

Figure 7: Mean heart rate after 12 minutes of submaximal work.

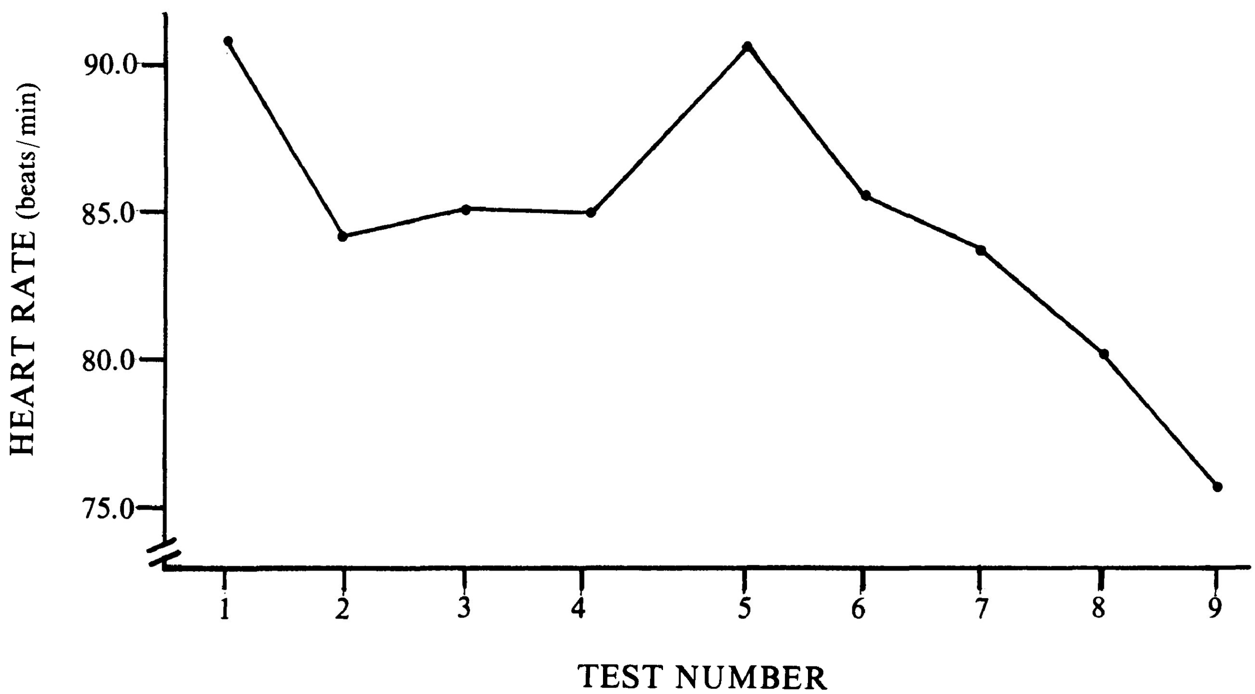

Figure 8: Mean five minute recovery heart rate after 12 minutes of submaximal work.

Table 12

Mean and percentage differences for PWC_{170}
(kpm/min)

Percentage Difference

Mean Difference

Test No.	1	2	3	4	5	6	7	8	9
1	—	.8	1.5	2.0	5.6	1.9	.8	3.3	6.3
2	+ 11	—	.7	2.8	6.3	1.1	0	2.5	5.5
3	+ 21	- 10	—	3.4	6.8	.4	.7	1.8	4.7
4	- 29	- 40	- 50	—	3.5	4.0	2.8	5.4	8.5
5	- 80	- 91	- 99	- 49	—	7.9	6.7	9.4	12.6
6	+ 27	+ 16	+ 6	+ 56	+107	—	1.1	1.4	4.3
7	+ 11	0	= 10	+ 40	+ 91	- 16	—	2.5	5.5
8	+ 47	+ 36	+ 26	+ 76	+127	+ 20	+ 36	—	2.9
9	+ 90	+ 79	+ 69	+119	+170	+ 63	+ 79	+ 43	—

Tukey value at 0.05 level = 194*

Table 13

Mean and percentage differences for PWC_{170}
(kpm/min/kg)

Percentage Difference

Mean Difference

Test No.	1	2	3	4	5	6	7	8	9
1	—	1.5	2.5	1.0	3.9	1.5	2.0	4.4	8.9
2	+ .27	—	1.0	2.4	5.3	1.9	.5	2.9	7.3
3	+ .45	- .18	—	3.4	6.3	3.9	.5	2.9	6.3
4	- .19	- .46	- .64	—	3.0	.5	3.0	5.5	10.0
5	- .87	-1.14	-1.32	- .68	—	7.7	6.2	8.7	13.3
6	+ .31	+ .58	+ .76	+ .12	+ .56	—	1.4	1.0	5.2
7	+ .37	+ .10	- .08	+ .56	+1.24	- .68	—	2.4	6.8
8	+ .94	+ .83	+ .47	+1.11	+1.79	+1.23	+ .55	—	4.3
9	+1.78	+1.51	+1.33	+1.97	+2.35*	+2.09	+1.41	+ .96	—

Tukey value at 0.05 level = 2.17*

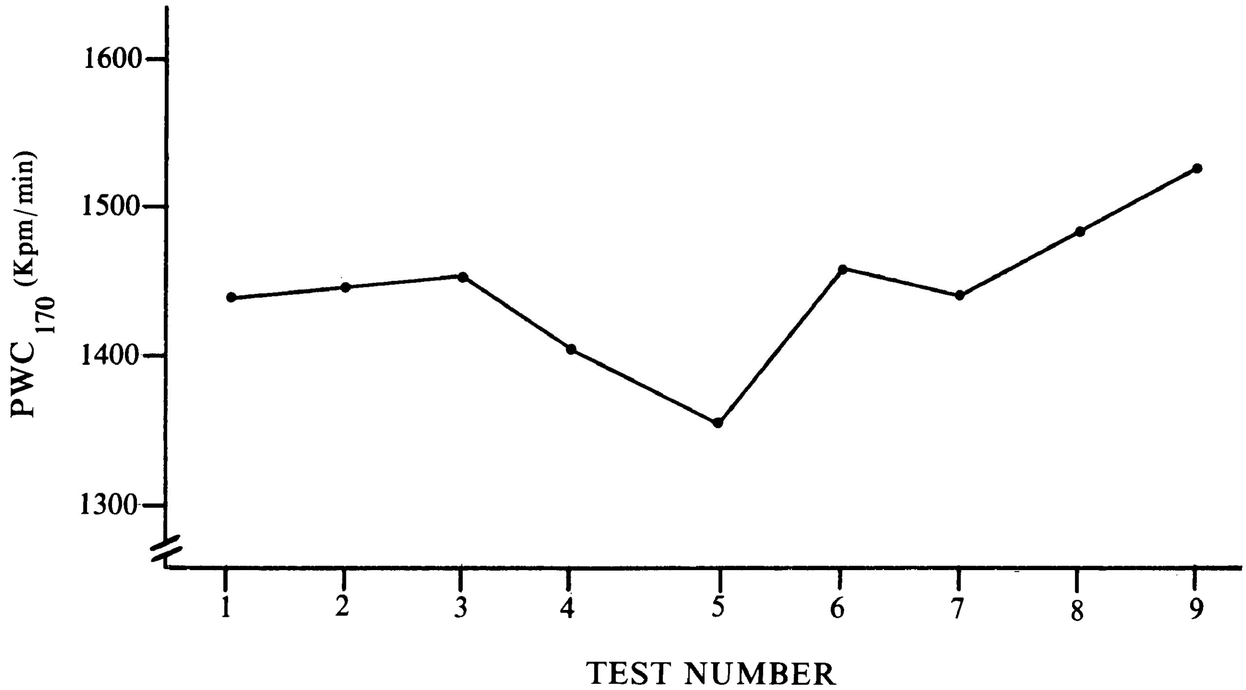

Figure 9: Mean PWC $_{170}$ in kpm/min.

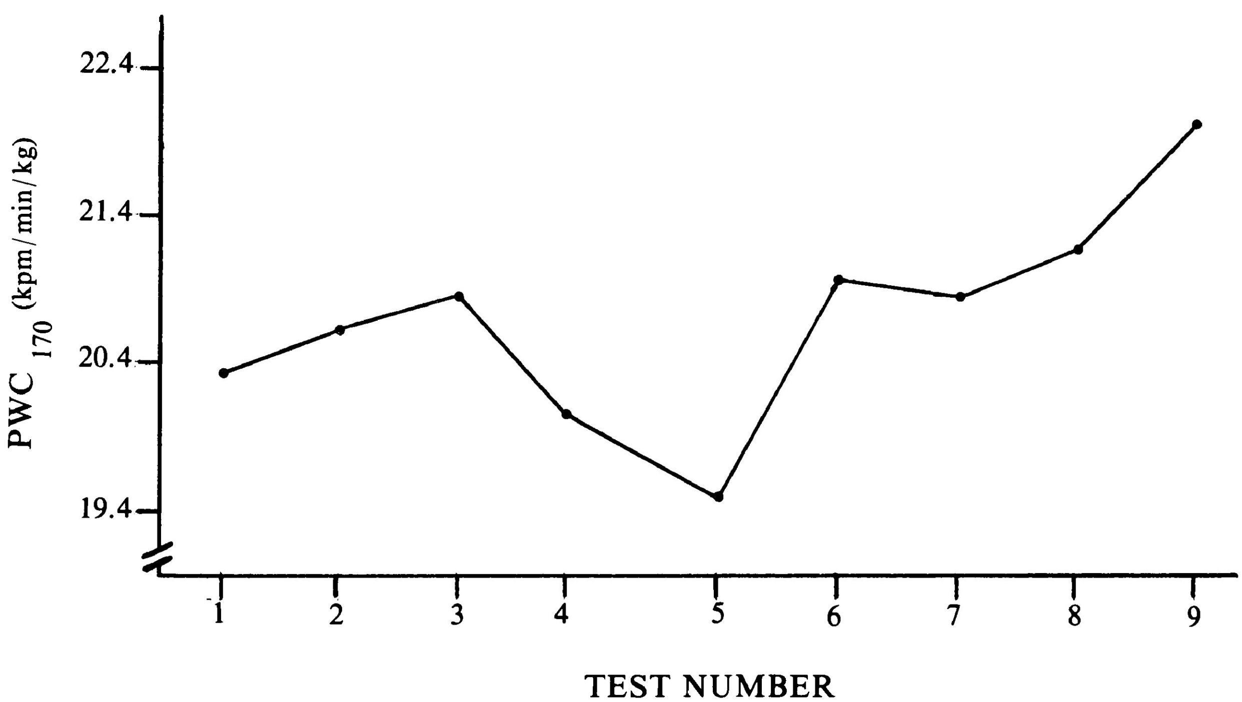

Figure 10: Mean PWC $_{170}$ in kpm/min/kg.

Table 14

Mean and percentage differences for anaerobic power
(kpm/40sec)

Percentage Difference

Mean Difference

Test No.	1	2	3	4	5	6	7	8	9
1	—	0	2.3	.3	1.8	.1	.8	1.7	.6
2	0	—	2.3	.3	1.8	.1	.8	1.7	.6
3	+ 51	+ 51	—	1.9	4.0	2.4	1.4	.5	1.6
4	+ 7	+ 7	- 44	—	2.0	.5	.5	1.4	.3
5	- 40	- 40	- 91	- 47	—	1.7	2.6	3.6	2.5
6	- 3	- 3	- 54	- 10	+ 37	—	.9	1.9	.8
7	+ 18	+ 18	- 33	+ 11	+ 58	+ 21	—	.9	.2
8	+ 39	+ 39	- 12	+ 32	+ 79	+ 42	+ 21	—	1.1
9	+ 14	+ 14	- 37	+ 7	+ 54	+ 17	- 4	- 25	—

Tukey value at 0.05 level = 152*

Table 15

Mean and percentage differences for anaerobic power
(kpm/40sec/kg)

Percentage Difference

Mean Difference

Test No.	1	2	3	4	5	6	7	8	9
1	——	.6	3.1	.9	1.3	.9	1.6	2.8	3.1
2	+ .23	——	2.5	.3	1.9	.3	.9	2.2	2.5
3	+ .99	+ .76	——	2.1	4.3	2.1	1.5	.3	0
4	+ .34	+ .11	- .65	——	2.2	0	.6	1.9	2.2
5	- .38	- .61	-1.37	- .72	——	2.2	2.9	4.1	4.4
6	- .31	- .08	- .68	- .03	+ .69	——	.6	1.9	2.2
7	+ .52	+ .29	- .47	+ .18	+ .90	+ .21	——	1.2	1.5
8	+ .94	+ .71	- .05	+ .50	+1.32	+ .63	+ .43	——	.3
9	+1.00	+ .77	- .01	+ .66	+1.33	+ .69	+ .47	+ .06	——

Tukey value at 0.05 level = 1.69*

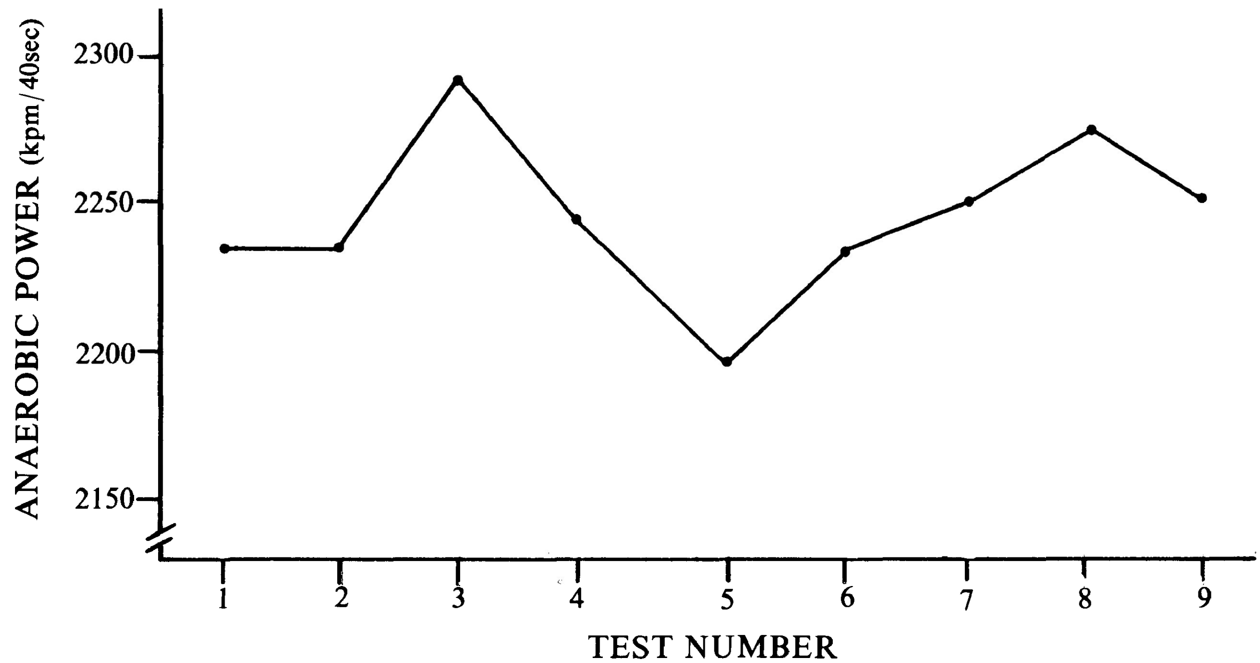

Figure 11: Mean anaerobic power in kpm/40sec.

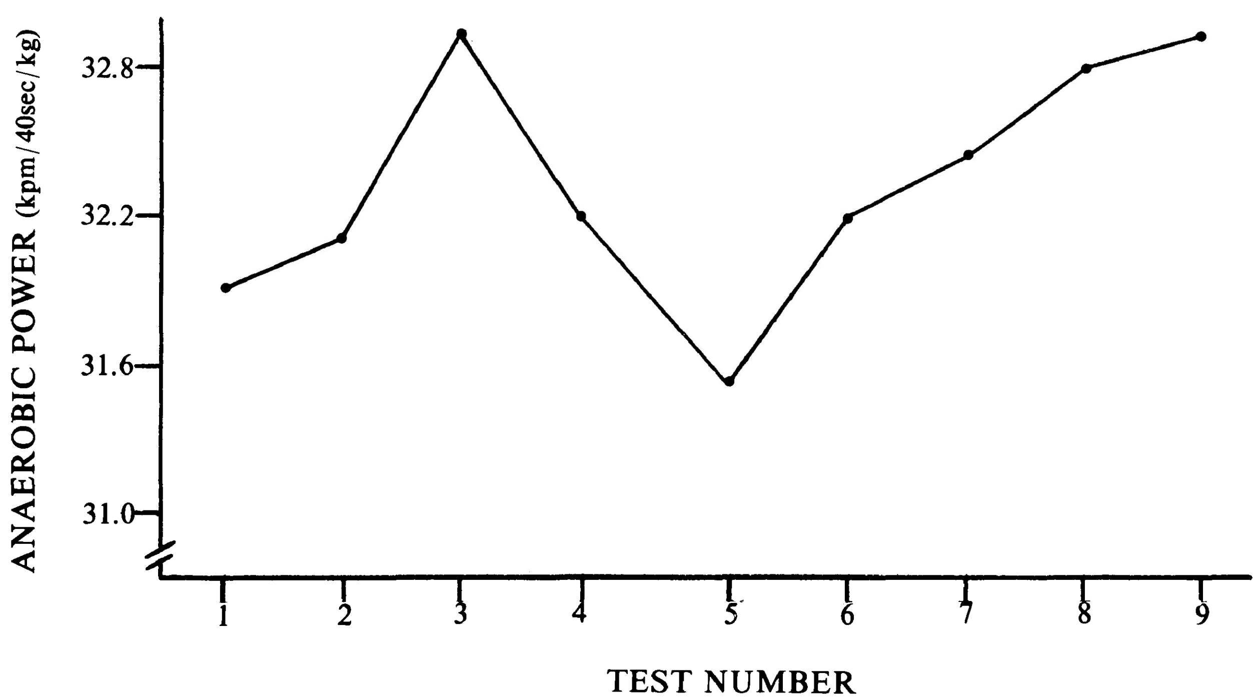

Figure 12: Mean anaerobic power in kpm/40sec/kg.

Chapter 5

DISCUSSION

Aerobic power

The mean pre-training (T_1) $\dot{V}O_2$ max of the wrestlers in the present study was 62.1 ml/kg/min which was above the values reported for sedentary populations of a similar age (Frick et al, 1963; and Rusko, Havu & Karvinen, 1978). In comparing the $\dot{V}O_2$ max of the wrestlers to other specialized athletes, the wrestlers had a moderate level of endurance capacity. Saltin and Åstrand (1967) reported VO_2 max values ranging between 52.0 and 85.1 ml/kg/min for a group of athletes representing various Swedish National teams. Recently, Pollock, Ayres, Ward, Sass and White (1975) demonstrated that the aerobic capacities of elite distance and middle distance runners were 78.5 and 74.4 ml/kg/min, respectively. Bergh (1974) reported the highest ever $\dot{V}O_2$ max of 93.0 ml/kg/min for one Swedish cross-country skier.

The mean $\dot{V}O_2$ max of 69.0 ml/kg/min found for the present study at T_5 was greater than the mean $\dot{V}O_2$ max of 54.0, 57.5 and 60.9 ml/kg/min reported by Gale and Flynn (1974), Saltin and Åstrand (1967) and Nagle et al (1975), respectively, for free-style wrestlers. However, the $\dot{V}O_2$ max of the present study was similar to the $\dot{V}O_2$ max of 65.5 and 66.6 ml/kg/min reported by Kelly et al (1978) and Fahey et al (1975) for six free-style wrestlers qualifying for the National championship and two NCAA and PCAA champions, respectively.

The slightly higher $\dot{V}O_2$ max of the present sample may be due to the relatively lower mean body weight (68.7 kg at T_9) than the mean body weight of 77.7 and 77.5 kg in the studies by Nagle et al (1975) and Gale and Flynn (1974), respectively. The lower mean body weight of the present study was due to the lack of representatives of the heavyweight (80 to 100 kg) and super heavyweight (100+ kg) categories. Additionally, Gale and Flynn (1974) found that the representatives of these weight categories exhibited $\dot{V}O_2$ max values lower than 40.0 ml/kg/min.

The mean $\dot{V}O_2$ max of the wrestlers was similar to that of hockey and soccer players (Withers, Roberts & Davies, 1977; and Raven et al, 1976), and was greater than swimmers, volleyball and basketball players and alpine skiers (Parnat et al, 1975; and Rusko et al, 1978).

It is not unusual to find the $\dot{V}O_2$ max of the wrestlers comparable to those of hockey and soccer players since the tasks confronting these athletes have basic similarities, ie. controlling and moving another resisting person for short periods of time.

Due to the escape rule in free-style wrestling (no points are awarded for an escape and a return to a standing position after about 15 seconds on the mat, if no pin is near) this type of wrestling is characterized by short spurts of activity during the takedown. The activity in the game of hockey and soccer is very similar where the athlete works very intensely for short periods of time.

Since a wrestling bout is characterized by dynamic spurts of activity followed by less intense periods of activity, it is not surprising that the $\dot{V}O_2$ max of the wrestler is not as high as other athletes who participate in events characteristic of more continuous activity for durations similar to the nine minute wrestling bout. In 1976, Costill and co-workers found that the $\dot{V}O_2$ max of middle distance runners were 70.1 ml/kg/min. This value is considerably higher than most wrestlers, yet the duration of the activity that both athletes partake in is similar.

As previously indicated a considerable part of free-style wrestling is explosive in nature. Jesse (1976) indicated that one of the essential pre-requisites to success is for the wrestler to have a high composition of fast-twitch, glycolytic-type fibres capable of producing large amounts of energy in short periods of time. Although no intensive study has been done on free-style wrestlers that determined the percentage of muscle fibre type and the biochemical adaptations to wrestling training, it becomes fairly evident that the better performers are quicker, stronger, more explosive and are able to maintain a higher tempo of activity for the entire duration of the nine minute bout.

It has been shown (Fox et al, 1973; Faria, 1970; and Pollock et al, 1969) that intensity, duration and frequency of exercise as well as age and the initial level of fitness are all critical factors influencing the rate of adaption of the aerobic system. On the basis of the acute response of the heart rate, it appeared that intensity was sufficient to stimulate improvement in the cardio-respiratory system (Sharkey & Holleman, 1967) as heart rates following a wrestling bout or the conditioning period frequently exceeded 95% of the maximal response (personal communications). The training sessions were of sufficient duration and frequency such that cardiovascular modifications were strongly favoured. As a result of 18 weeks of typical wrestling training, $\dot{V}O_2$ max showed an 11.1% improvement. An increase of this magnitude is supported by the studies of Reilly and Thomas (1977), Fox et al (1975) and Kelly et al (1978).

The unavoidable interventions proved to be detrimental to $\dot{V}O_2$ max. Although subjects were specifically instructed to maintain their level of aerobic fitness over the intervention period, a mean of 4.8% decrease was evident between T_2 and T_3. The T_3 value was very similar to the pre-training (T_1) value and was lower than the T_2 value for every individual wrestler. This finding clearly indicated that the training effect that had taken place in aerobic power prior to the intervention period had totally deteriorated over the intervention period. If such an occurrence is unavoidable it is perhaps best if coaches concentrate on developing technical skills and competition tactics during the pre-Christmas phase of the training schedule and less emphasis on physical conditioning.

As indicated in Table 9, $\dot{V}O_2$ max showed a moderate increase between T_4 and T_5 (5.0%). Such an increase is considerable within a four week period especially when the initial level was relatively high (65.0 ml/kg/min). It is not unusual for many coaches to put on a "final push" during the final phase of the training schedule in an attempt to get the athletes in peak physical condition at the time of the College and National championships. In many cases, the training sessions during this phase are considerably increased in intensity and the amount of time spent in productive work as defined by Rushall (1977) is greatly increased. The major drawback to employing such a tactic is that unless the coach is extremely careful, he may be imposing too much of a work load and consequently the athletes may in fact be overtraining, thus adversely affecting their performance at the College and National championships.

When the peak mean $\dot{V}O_2$ max (73.4 ml/kg/min) for the five wrestlers who performed well at the College championships (won two or more matches) was compared to the rest of the group (65.3 ml/kg/min) a definite difference existed. While a difference of less than 10 ml/kg/min appears far from impressive, it may represent a significant advantage in high level performance.

Although the sport of amateur free-style wrestling requires many other attributes in addition to aerobic power, the data from the present study support the contention that cardiovascular conditioning is an extremely important component of wrestling success.

Anaerobic power

An improvement in anaerobic power as reflected by the test protocol developed by Katch et al (1977) yielded no significant changes throughout the training period. Utilizing different techniques that are supposedly reflective of anaerobic capabilities, Green and Houston (1975) reported an increase of 16.3% in anaerobic power following five months of ice hockey training, and Schreiber (1973) reported an enhancement in anaerobic power for all athletic groups investigated after eight weeks participation in their sport specialty.

In addition, Schreiber (1973) reported that all sport specialists with the exception of the basketball representatives improved upon their run time on a short exhaustive run following training. Cunningham and Faulkner (1969) reported a 23% improvement for run time on a short exhaustive run following six weeks of interval sprint training.

The findings of the present study are in agreement with the findings of Coleman et al (1974) who reported that a group of basketball players failed to show any improvement in anaerobic power following 20 weeks of basketball training.

One of the major difficulties encountered when attempting to compare the findings of anaerobic power on different sportsmen is the inconsistency in the presentation of anaerobic power. Unlike aerobic power ($\dot{V}O_2$ max) where the findings are always reported in standardized units (L/min or ml/kg/min), anaerobic power is presented in various units. Consequently, a comparison of anaerobic power by different investigators on similar specialized athletes is often not possible.

In an analysis of anaerobic power on 116 athletes taking part in the XIX Olympic games, Di Prampero, Limas and Sassi (1970) found that if the maximal anaerobic energy expenditure was expressed in equivalent to oxygen consumption per kg of body weight the pentatheletes ranked highest (215 ml/kg/min), followed by the wrestlers (195 ml/kg/min). However, when expressed in absolute terms the wrestlers ranked lower than the pentathletes, sprinters and middle distance runners.

Schreiber (1973) found that the wrestlers and the football players exhibited the greatest anaerobic power output of 175.0 and 171.5 kg-m/sec, respectively, by using a Margaria-Kalman test.

The data indicated that anaerobic power remained stable throughout the training period. As can be seen in Table 3, the lowest value of 2195 kpm/40sec was found in T_5, whereas, the highest value of 2286 kpm/min was found in T_3.

The utilization of the test protocol developed by Katch et al (1977) to determine anaerobic power on the wrestlers has considerable applicability. As previously indicated, short spurts of action are characteristic of amateur free-style wrestling during the takedown. Such being the case, the wrestler must produce large amounts of energy throughout the entire sequel of action rather than merely upon the initiation of the particular technique. In many cases the sequel of action surpasses 30 seconds duration. Thus, an anaerobic power test that determines the power output over a 40 second period will possibly distinguish between the good wrestlers and the average to poor wrestlers.

Although no improvement was found for anaerobic power over the training period, the subjects were able to perform the 40 second test with less physical discomfort as the season progressed. During the initial testing sessions several subjects were virtually unable to walk following completion of the test. However, during the final phase of the training schedule, the subjects were performing equal amounts of anaerobic work with less severe physical discomfort following completion of the test. Previous investigators (Karlsson et al, 1972; Mathews & Fox, 1976; and Cunningham & Faulkner, 1969) have indicated increases in the ATP levels in the muscle, increased alkaline reserves, increased glycolytic enzymes and general increased strength of the muscle responsible for such an occurrence.

In comparing the anaerobic power of the successful wrestlers (winning two or more matches at the college championships) to the unsuccessful), the successful group (N=5) had lower anaerobic power than the unsuccessful group (32.0 compared to 33.4 kpm/40sec/kg). The slightly lower mean value of the successful group was due to one extremevvalue of 26.9 kpm/40sec/kg. On the basis of this data it is apparent that there were no differences in anaerobic power between the successful and unsuccessful wrestlers and it may be concluded that anaerobic power is not a feature which distinguishes between the successful and unsuccessful wrestlers.

Physical Working Capacity 170 (PWC_{170})

The only significant difference ($p < .05$) found for PWC_{170} was between T_5 and T_9 when expressed in kpm/min/kg. As can be seen in Table 12, other mean differences were apparent, however, they failed to reach the significant level. The difference between T_5 and T_9 of 2.60 kpm/min/kg is equivalent to 13.3%. Previous studies (Watson, 1978; Frick et al, 1963, 1970 and Crews and Roberts, 1976) have reported similar improvements for PWC_{170} following a training program. Watson (1978) found that PWC_{170} increased by 14.6% in previously non-athletic subjects following five weeks of controlled interval training.

Contrary to the findings of the present study, Watson (1978) found that PWC_{170} per kg of body weight increased for the non-athletes but was unchanged in the athletes. In the present study, PWC_{170} failed to show any improvement when expressed in absolute terms. One explanation offered for the controversial finding was that the subjects in the present study maintained a relatively stable body weight (details are shown in Table 3) throughout the investigative period up to the final testing session. Since the last testing session was just prior to the College wrestling championships, most subjects were in the process of reducing their body weight to their pre-designated weight category.

Due to the limited number of investigations on PWC_{170} an extensive comparison between specialized athletes was not possible. In comparing the findings of the present study to the available reports it was evident that the PWC_{170} of the present sample was greater than sedentary individuals before and after having completed a training program (Frick et al, 1963; and Crews & Roberts, 1976) that of the first and second year specialty students of physical education (Watson & O'Donovan, 1977) and superior to the findings of Ribisl and Herbert (1970) on college wrestlers. However they were of the same magnitude as the findings of Giesielievich (1974) for mature 20 to 35 year old wrestlers.

Giesielievich (1974) found that the PWC_{170} of international calibre wrestlers was greater in the representatives of the lower weight categories when expressed per kg of body weight. The 48 - 52 -

57 kg categories had the highest PWC_{170} (21.1 kpm/min/kg), followed by the 62 - 68 kg and 74 - 82 kg categories (20.9 and 20.5 kpm/min/kg), respectively, whereas, the 90 - 100 and 100^{+} kg categories ranked lowest with a mean value of 18.6 kpm/min/kg.

As can be seen in Figure 9 and 10, the PWC_{170} at T_5 was lower than the pre-training (T_1) value and of any other test value. This observation clearly indicated that the training effect that had taken place prior to the intervention period had totally deteriorated over four to five weeks of reduced or termination of training.

The relatively small increases in PWC_{170} found over the training program are attributed to the high initial levels as a result of the year round training that most College wrestlers undergo. It may also be due to the inability of the PWC_{170} test to depict small but perhaps significant improvements in the fitness level.

Although the intervention period was detrimental to PWC_{170} its absolute effect cannot be determined. This is due to the observation that within a two-week period following the interventions, PWC_{170} was equal to the pre-intervention value. It could possibly be that a break from the rigorous training schedule that College wrestlers undergo has greater psychological advantages than physiological disadvantages. Whether or not the wrestlers were more highly motivated to train harder following the intervention period is impossible to state.

<u>Resting, recovery and maximal heart rate</u>

Physical training in humans or animals will result in lower heart rates at rest and at submaximal work loads (Shaver, 1974a; Hartley et al, 1969; and Tipton, Carey, Eastin & Erikson, 1974). Some studies have shown that maximal heart rate can be decreased by physical training (Hartley et al, 1969; Magel et al, 1974; Pechar et al, 1974; and Rowell, 1974), however, other studies have reported no change in maximal heart rate following training (Kelly et al, 1978; Green & Houston, 1975; and Reilly & Thomas, 1977). The extent of the change has been stated by Pollock (1973) to be dependent upon intensity, frequency and duration of the training program, as well as age and the initial level of fitness.

The heart rate at rest showed a significant decrease ($p < .05$) following 18 weeks of wrestling training. Although free-style wrestling has been characterized as a predominantly anaerobic type activity (Jesse, 1976; and Lamb, 1978) and changes in the resting heart rate are more evident after completion of an endurance type program, the training session that the subjects underwent in the present study were structured so that both aerobic and anaerobic adaptations would occur. The outline of the Typical Training Session (Appendix A) indicates that the warm-up, review, demonstrative and experimental periods were performed at less than maximal intensity. Only the scrimmage and the extra conditioning period were performed at maximal intensity.

The decrease in the heart rate at rest and at submaximal work load are in accordance with the findings of previous investigators (Reilly & Thomas, 1977; Montgomery & Ismail, 1977; and Shaver, 1974a). In an investigation of the effect of a season of wrestling training on physiological parameters, Shaver (1974a) found that the mean resting heart rate decreased by 10 beats/min, submaximal exercise heart rates were reduced by 14.8 beats/min, and that the five minute recovery heart rate was significantly ($\underline{p} < .05$) lowered at each minute. The five minute recovery heart rate in the present study demonstrated a similar pattern.

Brouha (1962) indicated that for a standard amount of work the heart rate becomes slower as training progresses. Slower heart rates are observed even at rest and it is not exceptional for the resting pulse to be reduced by 10 to 20 beats/min between the beginning and end of a training period. The greater efficiency of the heart enables a larger blood flow to reach the muscles, ensuring an increased supply of fuel and oxygen, and permitting the individual to reach higher levels of performance. The findings of Brouha (1962) support the findings of the present study for the heart rate after 12 minutes of submaximal work. As the training progressed the heart rate at the 12th minute showed a progressive decline and reached the lowest rate in the final testing session.

The unavoidable interventions were detrimental to the resting, recovery and 12 minute heart rate. As illustrated in Figures 1, 3, 4, 7 and 8, the post-intervention values for these variables were less favourable than the pre-training (T_1) values. This finding indicates that a disruption in the training schedule of college wrestlers adversely affects cardiovascular efficiency.

The similar trend was found for other investigated variables, lower than untrained individuals of a similar age (Rusko et al, 1978), but were considerably higher than those of endurance runners reported by Koeslag and Sloan (1976) and Costill et al (1976). Additionally, the maximal heart rate of the present group was considerably greater than the findings of Nagle et al (1975) for a group of Olympic candidate wrestlers (193.5 compared to 176.0 beats/min).

The five minute recovery heart rate following maximal effort (RHR max) did not show any significant decrease after 18 weeks of wrestling training. This finding was partially explained through the observation that the run time for the $\dot{V}O_2$ max demonstrated a progressive increase with each successive test with the exception of T_3. This observation indicated that aerobic adaptations were occurring as a result of wrestling training, thus, permitting the subjects to stress themselves to a greater extent and consequently placing a greater overload on the circulatory system.

In summary, the findings of the present study support the findings of various investigators and the contention that cardiovascular adaptations will occur as a result of regular wrestling training.

Chapter 6

SUMMARY, CONCLUSIONS and RECOMMENDATIONS

Summary

The purpose of this study was to investigate the effect of seasonal wrestling training and unavoidable interventions on $\dot{V}O_2$ max, PWC_{170}, anaerobic power, resting and maximal and recovery heart rate and whether or not peak values for these parameters were achieved just prior to the College and National wrestling championships.

Utilizing a bi-weekly testing schedule for PWC_{170}, recovery heart rate and anaerobic power, and a monthly testing schedule for resting and maximal and recovery heart rate and maximum oxygen uptake, eleven potential varsity wrestlers were tested for the duration of 18 weeks while undergoing typical wrestling training.

The unavoidable interventions consisted of the examination period and Christmas holidays which extended from December six to the 18th and December 19th to January third, respectively.

The data were analyzed by a one-way analysis of variance and a Tukey test was applied to judge appropriate contrasts.

Conclusions

The following conclusions were made from the results of this study:

1. Cardio-respiratory fitness was enchanced through participation in 18 weeks of typical wrestling training as evidenced by:

a) significant increase in maximum oxygen uptake

b) significant decrease in the resting heart rate

c) significant decrease for the heart rate at a submaximal work load

d) significant decrease for the recovery heart rate following submaximal work

e) significant improvement in PWC_{170} when expressed per kg of body weight

2. Eighteen weeks of typical wrestling training had no effect on:

a) anaerobic power

b) maximal heart rate

c) recovery heart rate following maximal exercise

d) PWC_{170} when expressed in absolute terms

3. The unavoidable interventions had a non-significant effect on the variables investigated, however, the test values obtained immediately following the intervention period were less favourable than the pre-training values with the exception of the recovery heart rate following 12 minutes of submaximal work. This indicated that the training effect that occurred in the investigated variables prior to the intervention period totally deteriorated over five weeks of reduced and/or termination of training.

4. The relatively high level of fitness evident at the pre-training test (T_1) was attributed to the year round training that most of the subjects underwent.

5. The wrestlers of the present study were coached by a knowledgeable person who understood and applied physiological training

principles. This is evidenced by the level of fitness reaching a peak value just prior to the College and National championships.

Recommendations

One of the aims of applied physiological researchers is to provide coaches and athletes with information that will aid in producing superior performances. From the findings of this study it is recommended to coaches, athletes and future researchers that:

1. Aerobic training be included as part of the training program for college wrestlers.

2. In order to avoid deterioration of aerobic and anaerobic fitness over the intervention period, the coach outline specific programs for the wrestler to follow that will aid in maintaining the fitness level.

3. Coaches avoid scheduling important competition within a two-week period following the end of the intervention period. The two-week period will aid the wrestler in regaining some form of fitness and thus reduce the risk of injury.

4. If the scheduling of important competition is unavoidable within the first two weeks, that the coach drastically reduce the number of days that the wrestler reunite with his family during the festive season.

5. Future research investigating the effect of wrestling training and unavoidable interventions use National calibre wrestlers and employ a case study approach.

6. A study employing an experimental and control group be

carried out to determine the absolute effect of the unavoidable interventions. Such a study would resolve whether or not the level of fitness found at the time of the College and National wrestling championships was enhanced or adversely affected as a result of the unavoidable interventions.

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APPENDIX A

Typical Training Session:

Warm-up: (10 to 20 minutes)

A warm-up serves a dual purpose (Mathew & Fox, 1976); 1) it serves to reduce the risk of injury by preparing the body for the upcoming physical stress, 2) it enhances physical conditioning. As the season progresses the warm-up is shortened by approximately ten minutes while the intensity is increased. The shorter warm-up allows a greater amount of time for skill development and actual wrestling scrimmage.

A typical warm-up is made up of five minutes of slow jogging around the mat surface with several sprint intervals (10 seconds) implemented into the jogging. Following this, the wrestlers perform stretching exercises including all body joints. Such exercises as alternate toe touching, hurdler's stretch, arms, neck, trunk, and knee rotations, and exercises which stretch out the shoulder region are performed.

Review Period: (20 to 25 minutes)

This period is commonly referred to as "drilling". During this period wrestlers work in pairs and review the wrestling maneuvers learned the previous day or techniques with which they are very familiar. Over-learning the techniques is a common practise in wrestling. All techniques are done at 70 to 80 percent speed so as to simulate actual wrestling conditions.

Demonstrative and Experimental Period: (20 to 25 minutes)

During this period the coach introduces new wrestling maneuvers or reviews previously demonstrated ones. He displays their application and effectiveness prior to letting the wrestlers pair up and practice them.

In the final stages of this period the wrestlers are placed in simulated match situations where the effectiveness of the technique is tested. This final stage is carried out at very high intensity, once again to simulate actual wrestling conditions.

Scrimmage Period: (20 to 25 minutes)

During this period actual wrestling takes place. The wrestlers either pair up or are assembled into groups of three or four. They wrestle each other for the total time duration emphasizing either takedowns or partĕr wrestling.

Extra Conditioning: (1 to 5 minutes)

This time period is spent in performing high intensity work. The work performed may be in the form of wind sprints, relay races, or rope skipping.

APPENDIX B

Unavoidable Interventions

Examination Period

The examination period extended from the last day of regular scheduled classes to the last day that any one of the subjects involved in the study had an examination to write (December sixth to the 18th). The training sessions during this period were reduced to one hour in duration. Attendance was not optional, however, absence from the training session was tolerated if the individual had an examination to study for or write.

Christmas Holidays

The Christmas holidays were determined to commence December 19th and terminate January third. These dates represent the last date that an examination was written and the beginning of regular scheduled classes. Although there were regular scheduled training sessions on eight of the 18 days during this period, attendance was optional. Additionally, eight of the 11 subjects left campus during this period.

APPENDIX C

RAW DATA

Table A: Raw data for subject MS

Variables / Test No.	1	2	3	4	5	6	7	8	9
TESTED BI-WEEKLY									
Weight (kg)	58.1	57.1	56.7	57.0	54.7	55.0	56.3	54.6	51.4
PWC_{170} (kpm/min)	1029	900	907	1015	999	969	987	1004	1005
PWC_{170} (kpm/min/kg)	17.7	15.8	16.0	18.0	18.2	17.6	17.5	18.4	19.6
12th minute HR (beats/min)	154	168	170	155	158	162	157	154	152
RHR sub (beats/min)	95	85	97	72	80	88	85	82	79
Anaerobic power (kpm/40sec)	2013	2046	2013	2024	1969	1914	1914	1944	1845
Anaerobic power (kpm/40sec/kg)	34.6	35.8	35.5	35.3	36.0	34.8	34.0	35.6	35.9
TESTED MONTHLY									
Resting HR (beats/min)	54	—	60	—	57	—	57	—	54
Maximal HR (beats/min)	209	—	214	—	218	—	222	—	205
RHR max (beats/min)	115	—	112	—	116	—	123	—	96
$\dot{V}O_2$ max (L/min)	4.00	—	4.09	—	3.84	—	3.86	—	4.12
$\dot{V}O_2$ max (ml/kg/min)	69.1	—	72.3	—	70.2	—	68.6	—	80.1
$\dot{V}_E$ (L/min)	104.5	—	107.5	—	103.5	—	100.1	—	114.9

Table B: Raw data for subject AD

Variables / Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	60.4	60.0	60.3	60.7	60.5	59.8	60.7	60.7	59.1
PWC_{170} (kpm/min)	1365	1343	1262	1358	1461	1475	1386	1380	1380
PWC_{170} (kpm/min/kg)	22.6	22.4	21.3	22.4	24.1	24.7	23.1	22.7	23.6
12th minute HR (beats/min)	159	159	164	161	156	155	160	161	157
RHR sub (beats/min)	82	75	78	70	68	66	76	77	71
Anaerobic power (kpm/40sec)	2013	1980	2112	2046	1914	1782	1914	2046	1998
Anaerobic power (kpm/40sec/kg)	33.3	33.0	35.0	33.7	31.6	29.8	31.9	33.7	33.8
					TESTED MONTHLY				
Resting HR (beats/min)	42	—	47	—	45	—	42	—	43
Maximal HR (beats/min)	184	—	187	—	188	—	185	—	194
RHR max (beats/min)	82	—	90	—	85	—	93	—	84
$\dot{V}O_2$ max (L/min)	4.09	—	4.28	—	4.23	—	4.36	—	4.40
$\dot{V}O_2$ max (ml/kg/min)	68.4	—	71.0	—	69.9	—	72.7	—	74.5
$\dot{V}_E$ (L/min)	133.3	—	111.5	—	116.2	—	132.7	—	118.2

Table C: Raw data for subject PJ

Variables \ Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	65.3	64.9	64.2	63.7	64.2	63.5	64.0	63.5	63.3
PWC_{170} (kpm/min)	936	1072	1050	1236	1107	1222	1200	1230	1290
PWC_{170} (kpm/min/kg)	14.2	16.5	16.4	19.4	17.4	19.2	18.8	19.4	20.4
12th minute HR (beats/min)	184	170	172	168	180	170	170	170	162
RHR sub (beats/min)	90	75	88	70	75	63	71	64	60
Anaerobic power (kpm/40sec)	2211	2277	2244	2178	2178	2211	2244	2242	2243
Anaerobic power (kpm/40sec/kg)	33.9	35.1	35.0	34.2	34.0	34.8	35.1	35.3	35.4
					TESTED MONTHLY				
Resting HR (beats/min)	51	—	41	—	50	—	45	—	42
Maximal HR (beats/min)	205	—	202	—	213	—	209	—	203
RHR max (beats/min)	106	—	106	—	108	—	100	—	96
$\dot{V}O_2$ max (L/min)	4.09	—	4.52	—	4.42	—	4.51	—	4.39
$\dot{V}O_2$ max (ml/kg/min)	62.6	—	70.4	—	68.8	—	70.5	—	68.7
$\dot{V}_E$ (L/min)	101.2	—	108.3	—	115.4	—	126.0	—	104.1

Table D: Raw data for subject CN

Variables / Test No.	1	2	3	4	5	6	7	8	9
TESTED BI-WEEKLY									
Weight (kg)	67.1	66.8	66.5	67.0	66.7	66.1	66.3	66.2	66.2
PWC_{170} (kpm/min)	1455	1482	1470	1538	1387	1460	1540	1471	1538
PWC_{170} (kpm/min/kg)	21.6	22.1	22.0	22.9	20.8	22.1	23.2	22.2	23.2
12th minute HR (beats/min)	173	171	174	168	179	172	167	176	168
RHR sub (beats/min)	95	91	93	89	100	96	90	90	83
Anaerobic power (kpm/40sec)	2112	2178	2112	2178	2046	2277	2244	2250	2250
Anaerobic power (kpm/40sec/kg)	31.5	32.6	31.8	32.5	30.7	34.5	33.9	34.0	34.0
TESTED MONTHLY									
Resting HR (beats/min)	50	—	50	—	52	—	52	—	50
Maximal HR (beats/min)	191	—	190	—	189	—	197	—	196
RHR max (beats/min)	105	—	100	—	100	—	109	—	109
$\dot{V}O_2$ max (L/min)	4.56	—	4.65	—	4.40	—	4.76	—	4.85
$\dot{V}O_2$ max (ml/kg/min)	68.0	—	71.1	—	66.1	—	71.9	—	73.4
$\dot{V}_E$ (L/min)	130.5	—	101.7	—	114.5	—	131.5	—	131.8

Table E: Raw data for subject AD

Variables / Test No.	1	2	3	4	5	6	7	8	9
TESTED BI-WEEKLY									
Weight (kg)	70.0	70.1	69.5	69.0	69.5	69.5	70.0	69.0	67.5
PWC_{170} (kpm/min)	1290	1375	1325	1225	1240	1297	1298	1335	1253
PWC_{170} (kpm/min/kg)	18.4	19.6	19.0	17.8	17.8	18.7	18.3	19.3	18.6
12th minute HR (beats/min)	161	153	155	171	165	160	159	159	165
RHR sub (beats/min)	95	88	74	98	98	75	88	75	80
Anaerobic power (kpm/40sec)	2244	2244	2277	2211	2178	2310	2277	2277	2241
Anaerobic power (kpm/40sec/kg)	32.0	32.0	32.8	32.0	31.3	33.2	32.1	33.0	33.2
TESTED MONTHLY									
Resting HR (beats/min)	52	—	52	—	51	—	52	—	50
Maximal HR (beats/min)	195	—	189	—	200	—	200	—	200
RHR max (beats/min)	106	—	108	—	105	—	101	—	100
$\dot{V}O_2$ max (L/min)	4.18	—	4.31	—	4.05	—	4.20	—	4.09
$\dot{V}O_2$ max (ml/kg/min)	59.7	—	62.1	—	58.4	—	59.2	—	60.7
$\dot{V}_E$ (L/min)	126.9	—	107.3	—	146.4	—	133.6	—	132.1

Table F: Raw data for subject LH

Variables / Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	70.7	71.5	71.5	71.5	72.2	73.2	71.7	71.6	70.2
PWC_{170} (kpm/min)	1890	1950	2040	1852	1675	2045	1845	1995	1990
PWC_{170} (kpm/min/kg)	26.7	27.3	28.5	25.9	23.2	27.9	25.7	27.9	28.3
12th minute HR (beats/min)	150	147	147	149	160	148	149	145	145
RHR sub (beats/min)	83	80	81	82	95	84	81	75	64
Anaerobic power (kpm/40sec)	2211	2343	2376	2343	2211	2343	2343	2341	2345
Anaerobic power (kpm/40sec/kg)	31.3	32.8	33.2	32.8	30.6	32.0	32.7	32.7	33.4
					TESTED MONTHLY				
Resting HR (beats/min)	47	—	51	—	55	—	55	—	46
Maximal HR (beats/min)	184	—	180	—	177	—	177	—	177
RHR max (beats/min)	92	—	82	—	84	—	85	—	79
$\dot{V}O_2$ max (L/min)	4.64	—	4.82	—	4.52	—	4.76	—	4.93
$\dot{V}O_2$ max (L/min)	65.2	—	67.4	—	63.0	—	66.5	—	70.0
$\dot{V}_E$ (L/min)	112.0	—	118.5	—	103.9	—	127.9	—	128.8

Table G: Raw data for subject SR

Variables / Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	72.2	71.5	72.2	73.5	74.0	73.0	72.5	73.5	73.5
PWC_{170} (kpm/min)	1584	1500	1668	1500	1441	1597	1537	1665	1597
PWC_{170} (kpm/min/kg)	21.9	20.9	23.2	20.4	19.5	21.6	20.9	22.6	21.7
12th minute HR (beats/min)	158	160	160	170	175	164	169	160	165
RHR sub (beats/min)	80	80	75	91	100	98	91	85	78
Anaerobic power (kpm/40sec)	2277	2244	2277	2244	2244	2277	2343	2279	2286
Anaerobic power (kpm/40sec/kg)	31.4	31.4	31.6	30.9	29.9	31.2	32.3	31.0	31.1
					TESTED MONTHLY				
Resting HR (beats/min)	46	—	45	—	50	—	45	—	50
Maximal HR (beats/min)	175	—	181	—	177	—	178	—	180
RHR max (beats/min)	80	—	94	—	91	—	90	—	89
$\dot{V}O_2$ max (L/min)	4.70	—	4.71	—	4.62	—	5.03	—	5.01
$\dot{V}O_2$ max (ml/kg/min)	65.5	—	65.1	—	61.1	—	69.4	—	68.4
$\dot{V}_E$ (L/min)	132.4	—	124.2	—	138.3	—	129.3	—	130.5

Table J: Raw data for subject BR

Variables / Test No.	1	2	3	4	5	6	7	8	9
TESTED BI-WEEKLY									
Weight (kg)	77.5	77.3	75.3	75.9	76.1	76.0	75.0	75.2	75.1
PWC_{170} (kpm/min)	1412	1425	1250	1170	1175	1365	1370	1362	1582
PWC_{170} (kpm/min/kg)	18.2	18.4	16.6	15.4	15.4	180	18.2	18.1	21.1
12th minute HR (beats/min)	163	155	167	174	172	158	157	158	148
RHR sub (beats/min)	93	85	93	94	102	84	73	76	70
Anaerobic power (kpm/40sec)	2475	2475	2442	2475	2442	2541	2607	2542	2553
Anaerobic power (kpm/40sec/kg)	31.9	32.0	32.4	32.6	32.1	33.4	34.8	33.8	34.0
TESTED MONTHLY									
Resting HR (beats/min)	66	—	60	—	60	—	57	—	50
Maximal HR (beats/min)	200	—	202	—	201	—	203	—	205
RHR max (beats/min)	112	—	110	—	115	—	114	—	111
$\dot{V}O_2$ max (L/min)	4.45	—	4.32	—	3.86	—	4.36	—	4.84
$\dot{V}O_2$ max (ml/kg/min)	57.5	—	57.4	—	50.8	—	58.2	—	64.5
$\dot{V}_E$ (L/min)	111.6	—	110.1	—	103.9	—	121.8	—	112.0

Table H: Raw data for subject CP

Variables \ Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	76.5	74.0	75.5	75.0	75.0	73.7	74.8	75.2	73.5
PWC_{170} (kpm/min)	1447	1500	1537	1527	1412	1590	1515	1530	1536
PWC_{170} (kpm/min/kg)	18.9	20.2	20.4	20.4	18.8	21.6	20.2	20.3	20.9
12th minute HR (beats/min)	163	161	159	158	168	158	160	160	161
RHR sub (beats/min)	92	92	83	85	97	91	92	95	87
Anaerobic power (kpm/40sec)	1980	2013	2046	1881	1980	1980	2013	2045	1977
Anaerobic power (kpm/40sec/kg)	25.9	27.2	27.1	25.1	26.4	26.9	26.9	27.2	26.9
					TESTED MONTHLY				
Resting HR (beats/min)	52	—	50	—	55	—	52	—	45
Maximal HR (beats/min)	182	—	181	—	193	—	186	—	184
RHR max (beats/min)	102	—	95	—	102	—	90	—	96
$\dot{V}O_2$ max (L/min)	4.34	—	4.47	—	4.43	—	4.71	—	5.08
$\dot{V}O_2$ max (ml/kg/min)	56.7	—	60.0	—	59.2	—	63.0	—	69.1
$\dot{V}_E$ (L/min)	111.6	—	110.6	—	99.9	—	129.4	—	125.9

Table I: Raw data for subject WM

Variables / Test No.	1	2	3	4	5	6	7	8	9
					TESTED BI-WEEKLY				
Weight (kg)	77.5	77.0	78.0	78.1	77.9	76.1	76.8	77.6	76.9
PWC_{170} (kpm/min)	1755	1710	1762	1695	1650	1710	1745	1895	1875
PWC_{170} (kpm/min/kg)	22.6	22.2	22.6	21.7	21.5	22.5	22.7	24.4	23.7
12th minute HR (beats/min)	154	157	153	158	161	157	155	145	148
RHR sub (beats/min)	95	90	91	92	92	90	86	88	84
Anaerobic power (kpm/40sec)	2475	2376	2541	2475	2409	2343	2409	2413	2376
Anaerobic power (kpm/40sec/kg)	31.9	30.9	32.6	31.7	30.8	30.8	31.4	31.1	30.9
					TESTED MONTHLY				
Resting HR (beats/min)	51	—	52	—	52	—	52	—	51
Maximal HR (beats/min)	186	—	186	—	195	—	189	—	193
RHR max (beats/min)	96	—	107	—	101	—	98	—	103
$\dot{V}O_2$ max (L/min)	4.82	—	4.95	—	4.70	—	4.91	—	5.19
$\dot{V}O_2$ max (ml/kg/min)	62.2	—	63.4	—	61.2	—	64.0	—	67.6
$\dot{V}_E$ (L/min)	120.1	—	116.7	—	125.1	—	123.3	—	118.3

Table K: Raw data for subject TJ

Variables / Test No.	1	2	3	4	5	6	7	8	9
TESTED BI-WEEKLY									
Weight (kg)	77.9	78.8	78.1	77.6	79.5	78.6	78.7	78.0	78.6
PWC_{170} (kpm/min)	1622	1650	1755	1350	1350	1345	1493	1435	1732
PWC_{170} (kpm/min/kg)	20.8	20.9	22.5	17.4	17.2	17.1	19.0	18.4	22.0
12th minute HR (beats/min)	156	157	151	170	170	172	161	165	159
RHR sub (beats/min)	93	80	78	90	90	93	84	76	74
Anaerobic power (kpm/40sec)	2574	2409	2706	2607	2574	2574	2475	2636	2609
Anaerobic power (kpm/40sec/kg)	33.0	30.6	34.7	33.6	32.7	32.8	31.5	33.8	33.2
TESTED MONTHLY									
Resting HR (beats/min)	53	—	53	—	51	—	50	—	51
Maximal HR (beats/min)	192	—	200	—	200	—	192	—	190
RHR max (beats/min)	90	—	92	—	99	—	100	—	92
$\dot{V}O_2$ max (L/min)	4.15	—	4.35	—	4.31	—	4.65	—	4.87
$\dot{V}O_2$ max (ml/kg/min)	54.8	—	57.8	—	55.3	—	59.1	—	62.0
$\dot{V}_E$ (L/min)	91.3	—	96.1	—	103.9	—	108.5	—	112.5

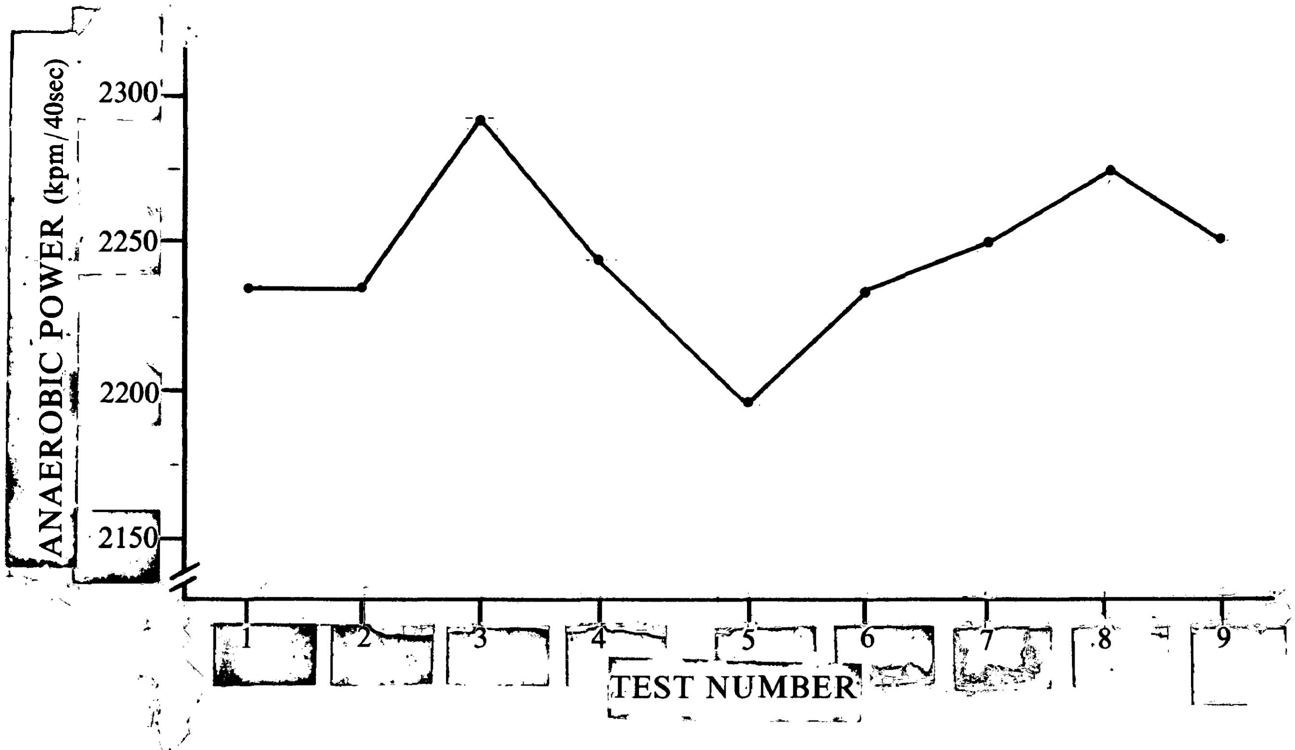

Figure 11: Mean anaerobic power in kpm/40sec.

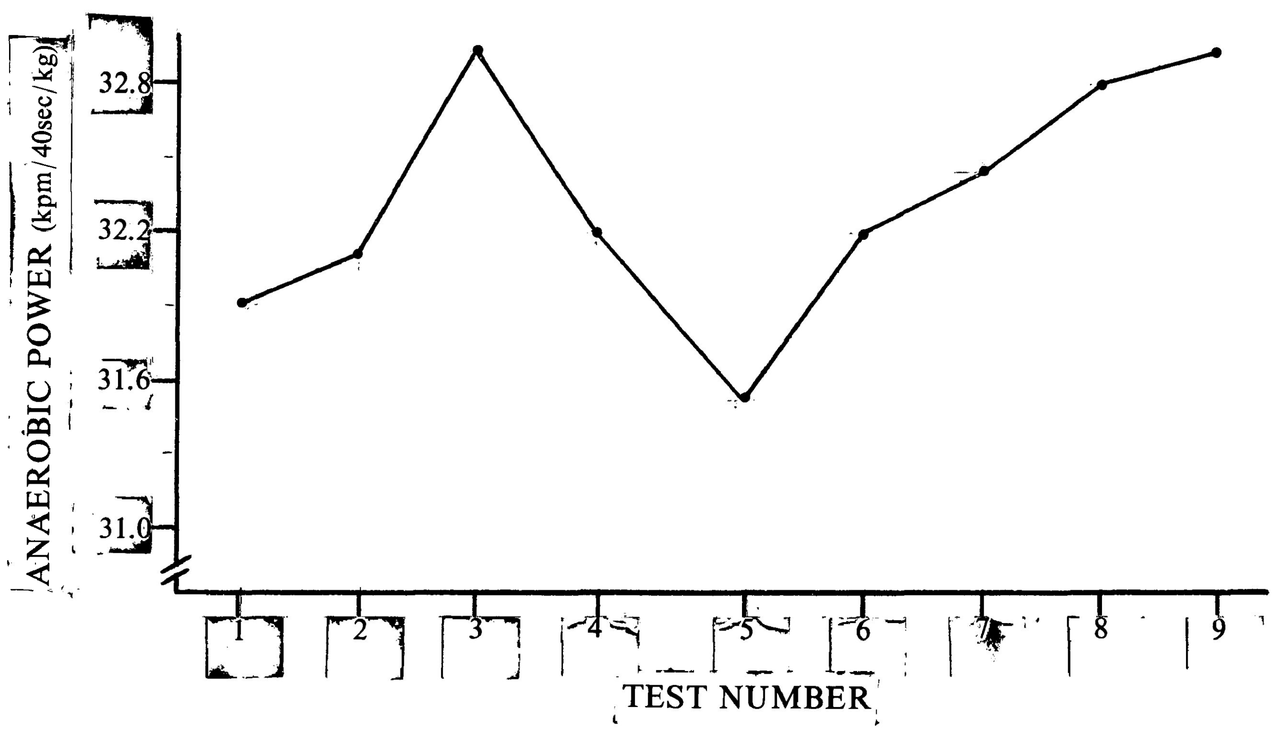

Figure 12: Mean anaerobic power in kpm/40sec/kg.

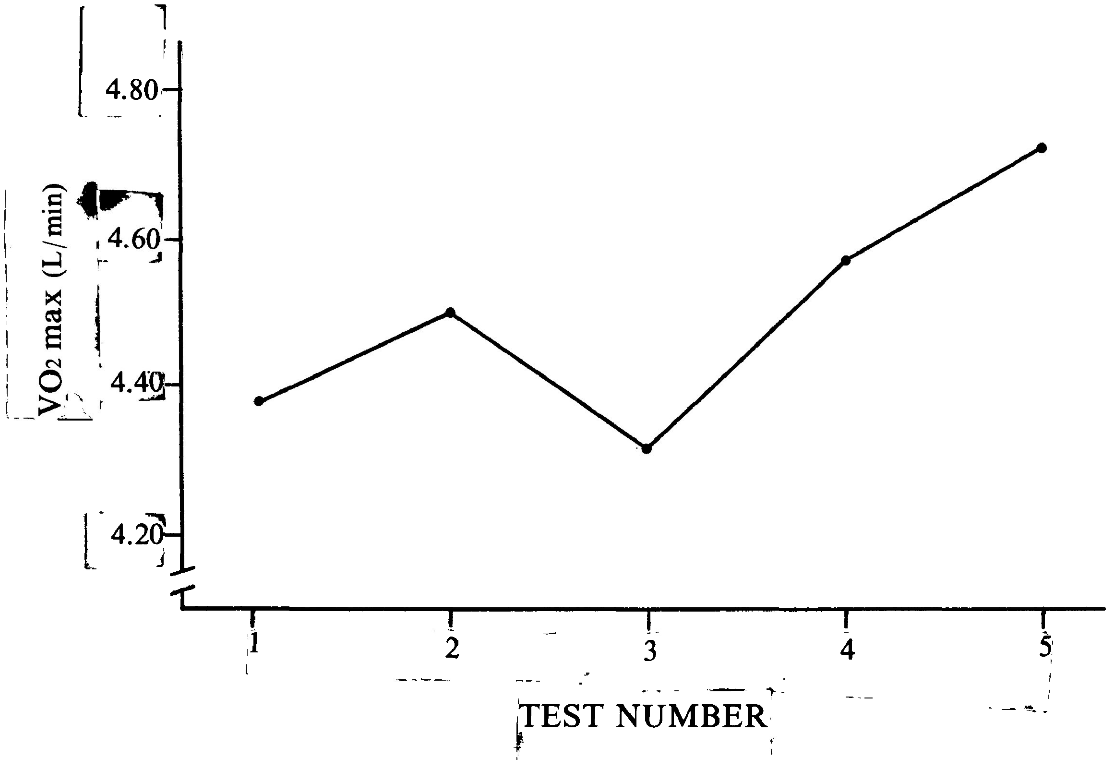

Figure 5: Mean values for maximum oxygen uptake in L/min.

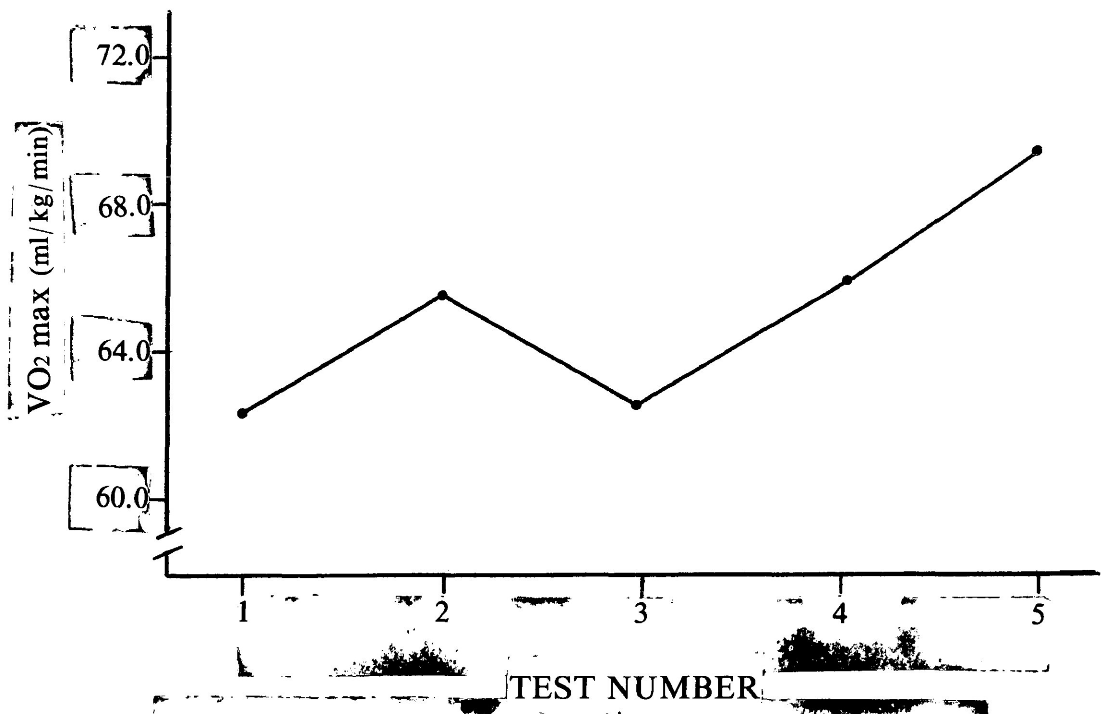

Figure 6: Mean values for maximum oxygen uptake in ml/kg/min.

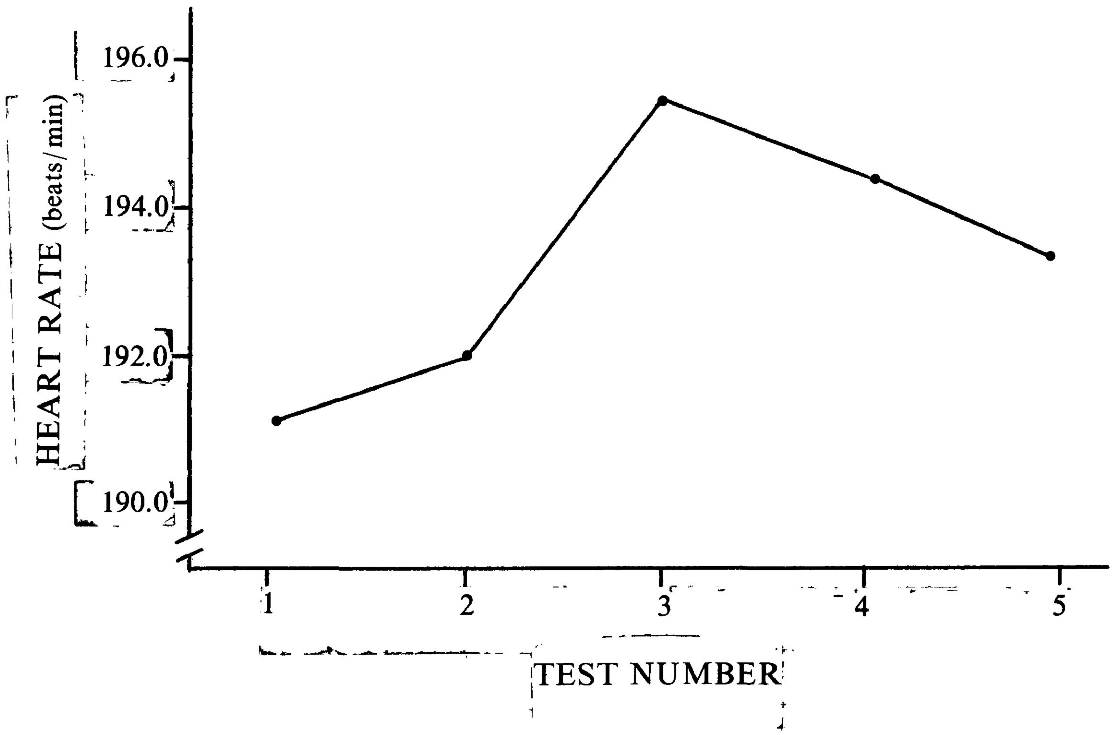

Figure 3: Mean maximal heart rate during maximal exercise.

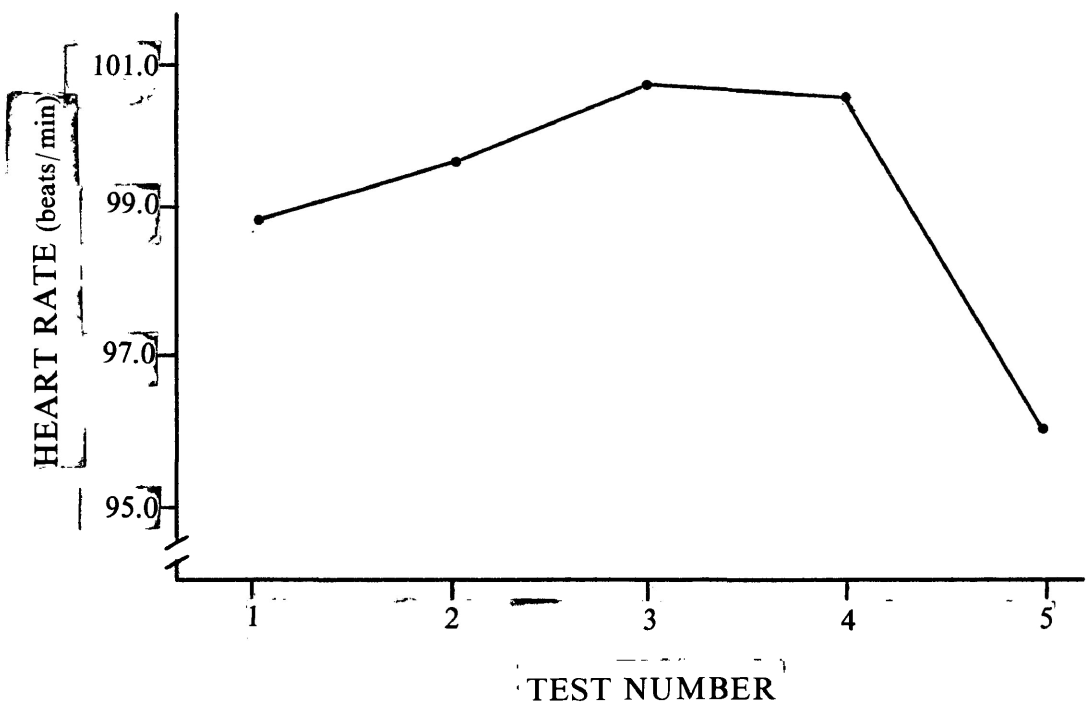

Figure 4: Mean five minute recovery heart rate after maximal exercise.

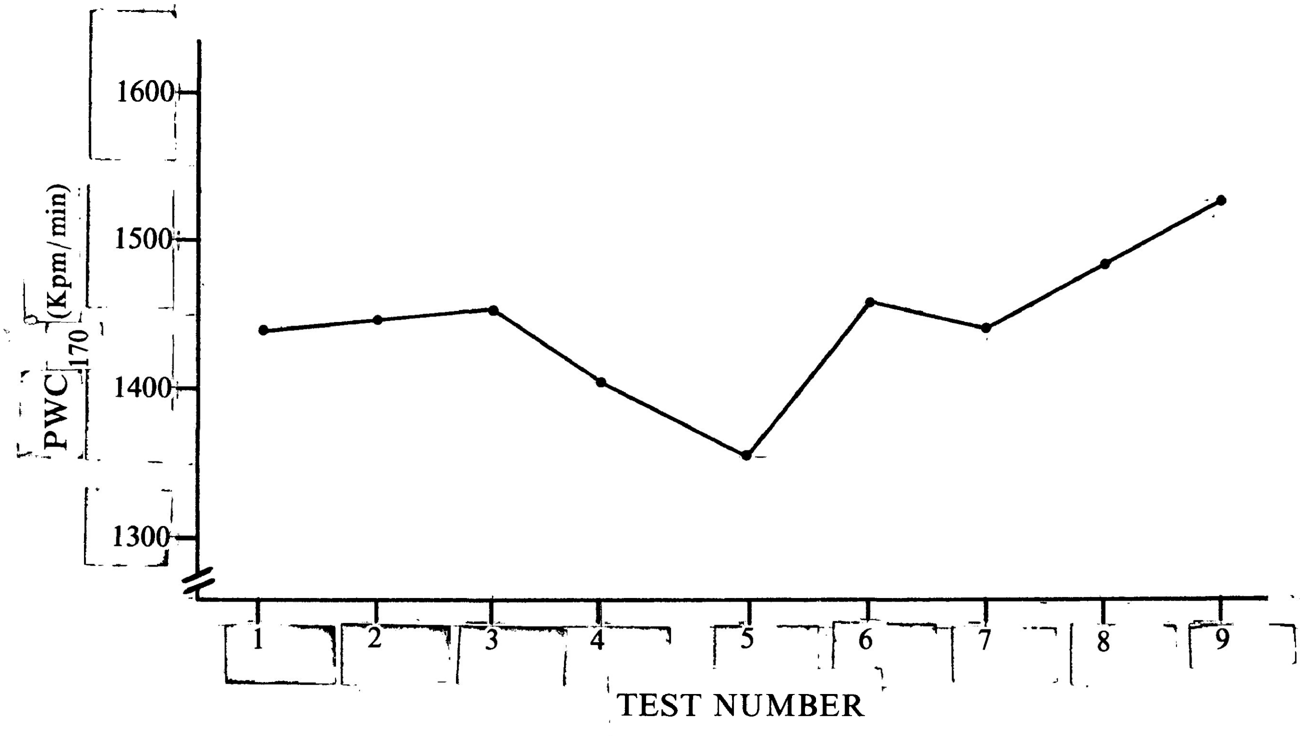

Figure 9: Mean PWC_{170} in kpm/min.

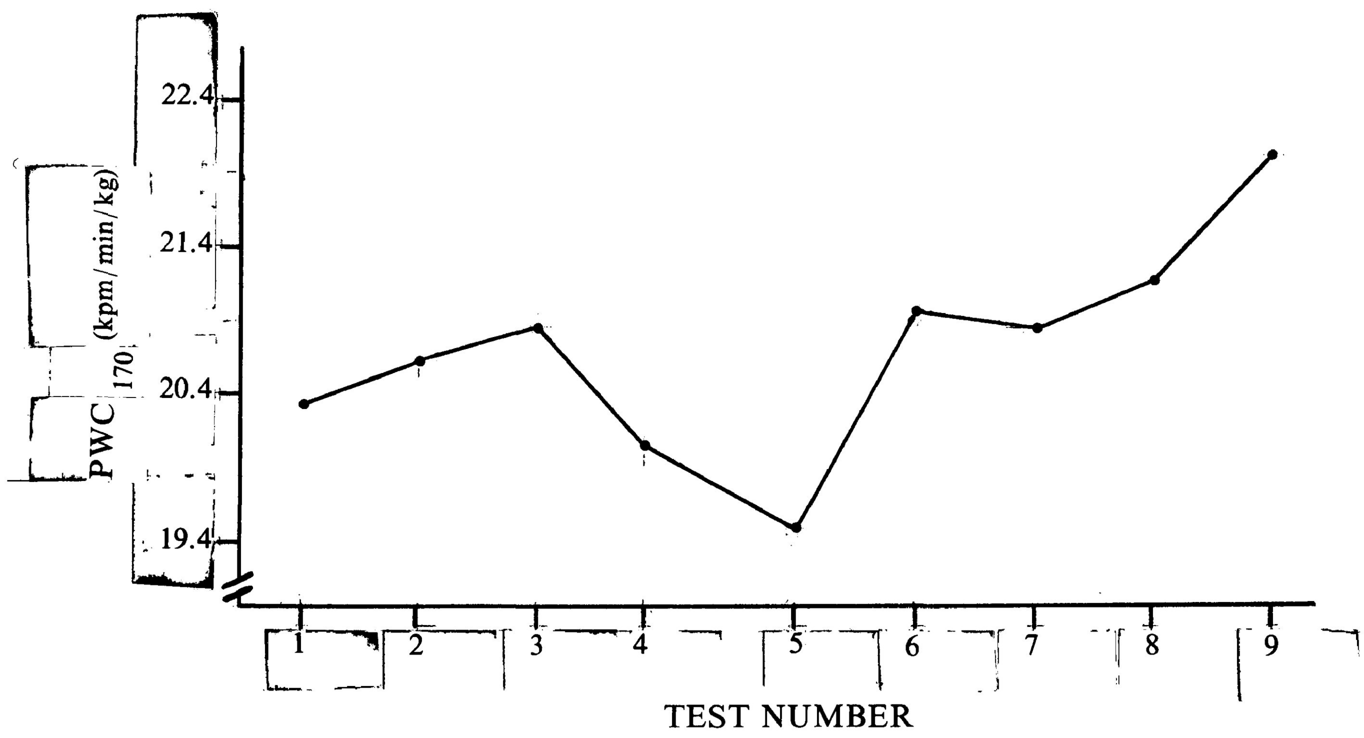

Figure 10: Mean PWC_{170} in kpm/min/kg.

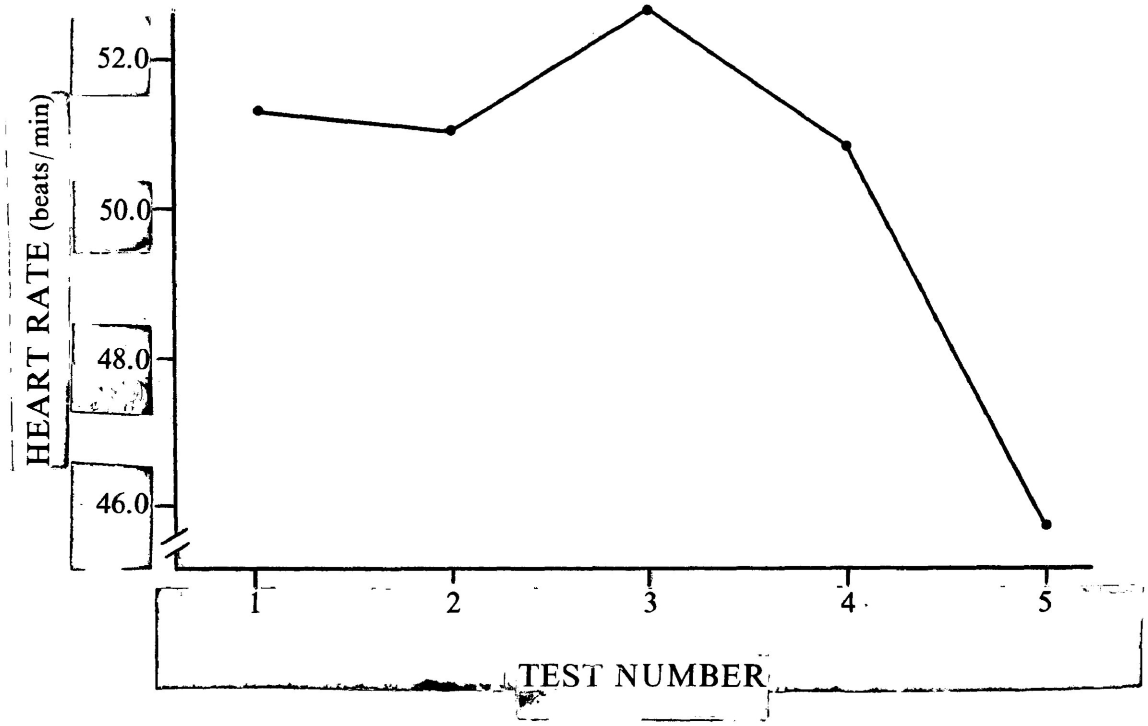

Figure 1: Mean resting heart rate.

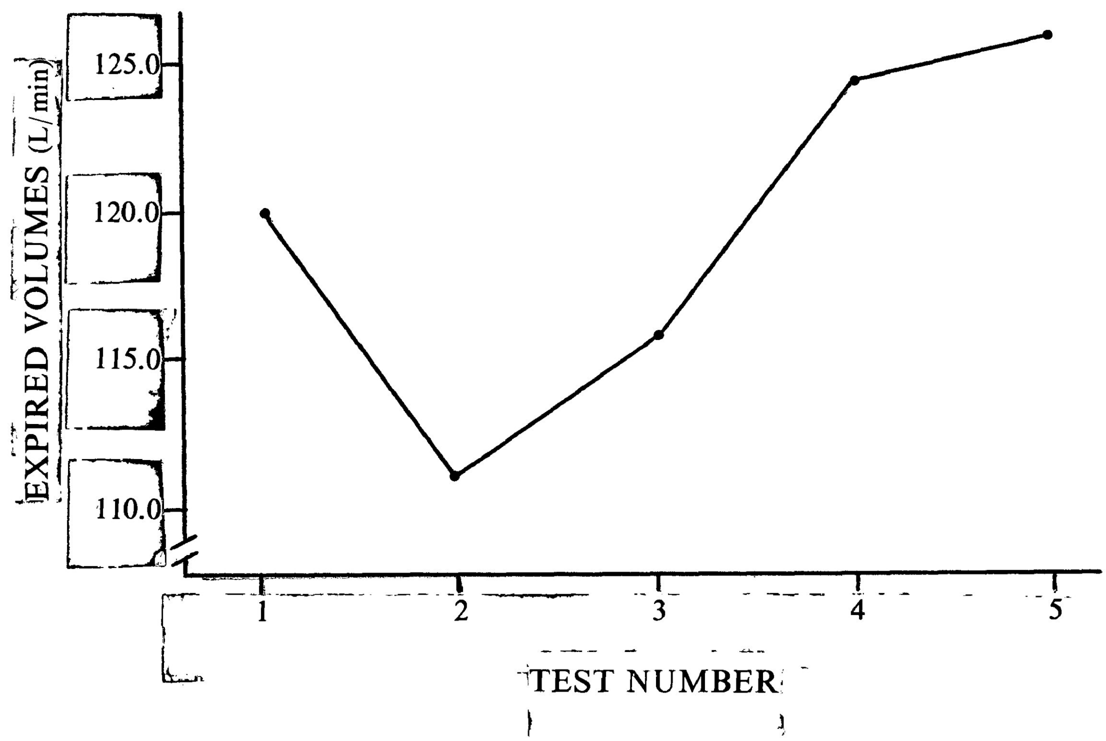

Figure 2: Mean expired volumes.

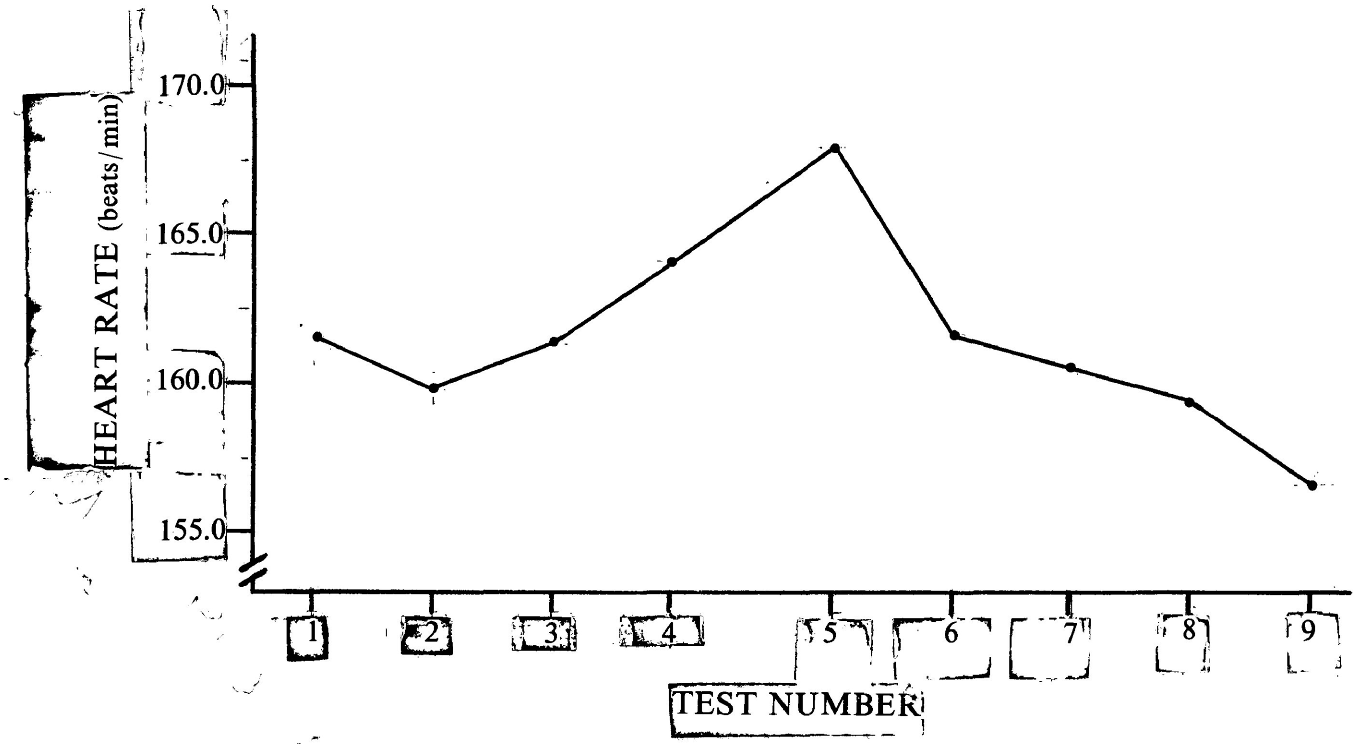

Figure 7: Mean heart rate after 12 minutes of submaximal work.

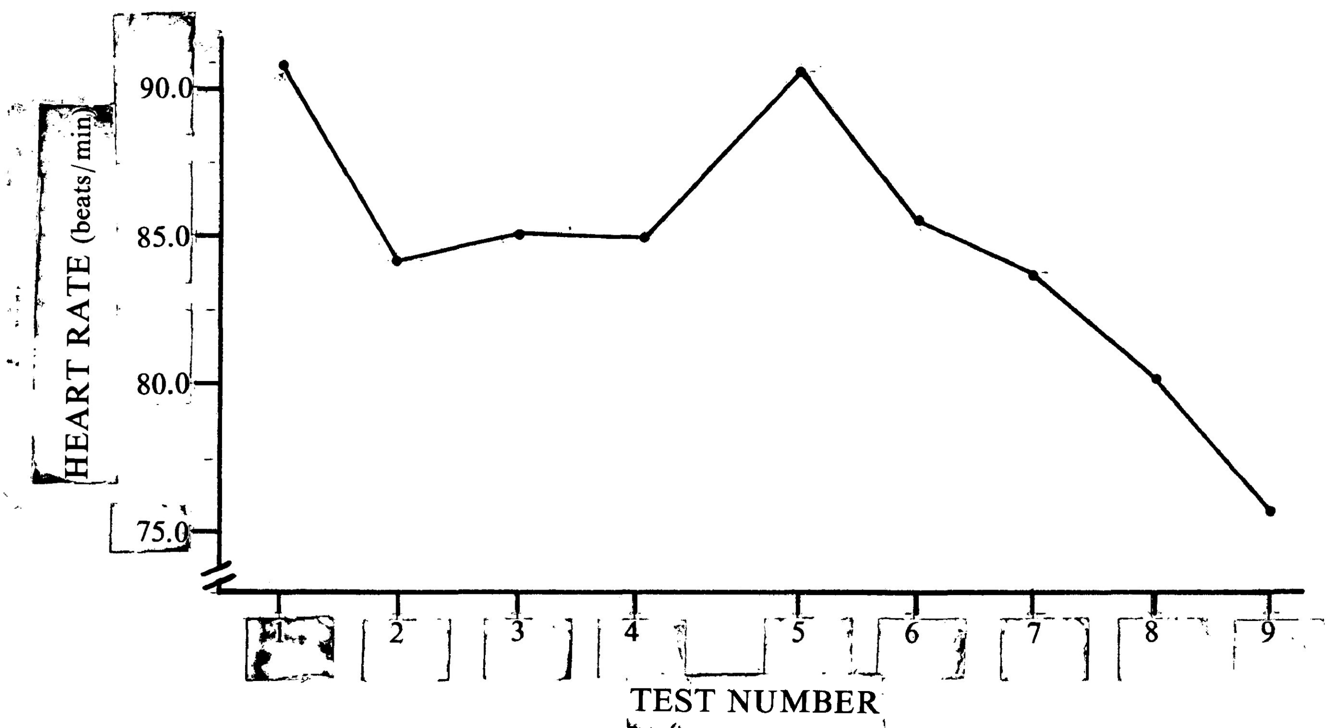

Figure 8: Mean five minute recovery heart rate after 12 minutes of submaximal work.